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Coastal Watersheds At Bay

A Watershed Awareness Curriculum

A Critical and Creative Thinking Approach
to Understanding How Land Uses in a Watershed
Affect Water Resources in a Coastal Drainage Basin.

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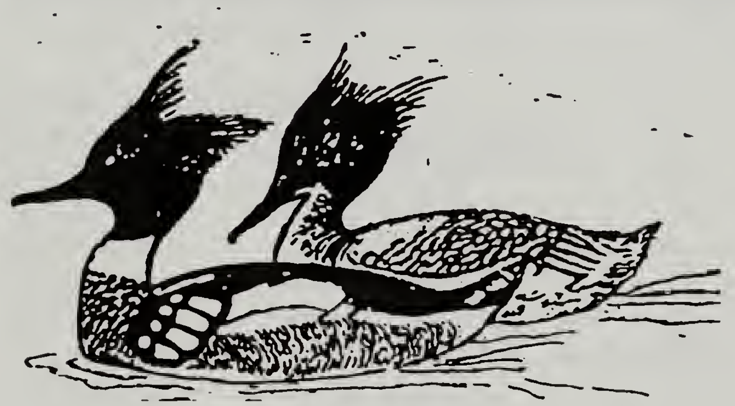
Part I

Curriculum Background and Development



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Curriculum Background

The Coastal Watersheds at Bay Curriculum focuses on groundwater and watershed dynamics and the impacts of human land use on these natural systems. Although the Waquoit Bay National Estuarine Research Reserve served as a model coastal drainage system for the curriculum, the activities are applicable to coastal watershed areas in general. Background information on the geology of Cape Cod and Waquoit Bay is included in the Primer for Educators. This background may serve as interesting, if not directly relevant, information for the study of your watershed. It is presumed that educators will supplement activities with pertinent background information about their specific locale.

Educators face the challenge of making the complex relationships between human needs (housing, energy, recreation) and environmental impacts understandable to their learners. This task is particularly important because a sound understanding of these relationships is critical if citizens are to make informed choices about the workings of society.

Recent emphasis on the need to control non-point source pollution requires a basic understanding of watersheds, groundwater and groundwater flow. In the absence of a solid foundation, many individuals harbor incorrect explanations about scientific concepts for years (Hawkins, 1985; Gallagher, 1987; Cole, 1990). For example, a recent survey found that educators on Cape Cod visualize aquifers as clear, underground, pools or rivers. In fact, aquifers are water-saturated underground sediments. On Cape Cod, water fills the minute spaces among the grains of sand and gravel. You can visualize this by pouring water into a container of dry sand. The water sinks in and displaces the air between sand grains.

This curriculum integrates history, language, mathematics and science to help learners grasp the basic concepts of watershed dynamics. Critical and creative thinking skills and strategies are the foundation of this approach. Group experimental learning and involved hands-on activities, peer interaction and teacher-facilitated discussion are integral parts of this method.

The aim of the Coastal Watersheds at Bay Curriculum is to foster the development of the following skills and strategies.

Critical Thinking Skills
comparing/contrasting
predicting/extrapolating
analyzing/synthesizing
hypothesizing/inferring
evaluating/concluding
classifying/categorizing

Creative Thinking
visualization
fluency
intuition
model building
developing insight
originality

Thinking Strategies
problem solving
decision making
critical thinking
strategic reasoning
syllogistic reasoning

To illustrate, the Raindrop Journey Activity functions as a creative thinking strategy by encouraging visualization and imagery. Likewise the Algal Growth Experiment helps learners develop hypotheses, make predictions and draw conclusions. Another activity uses a local issue, the Waquoit Bay Fish Kill, to foster problem-solving abilities.

Each curriculum activity follows the outline presented below.

1. Goal: the aim of the activity.

2. Summary: procedures used to achieve goals.

3. Time, place and materials: the sequence and timing of the activity.

4. Introduction and Motivation: the focus of the activity. To motivate learners, pique their curiosity and encourage them to ask questions, concepts are linked to familiar and interesting situations. For example, a provocative question or reading may stimulate interest.

5. Activity Procedure: investigating the question. Students discuss what they know or think they understand about the concept. For example, before explaining groundwater flow, the students may draw their ideas using the Watershed Cross-Section Diagram. The research or discovery process is directed by engaging students in tasks that use new points of view, unexplained phenomena, or discrepant events to challenge their existing ideas and depth of knowledge. To help learners assimilate new concepts, they may record observations for later discussions, incorporate models and analogies as links to abstract concepts, participate in peer interaction and group work, and practice using critical and creative thinking strategies and skills.

6. Closure: processing new information. Methods are developed to help students replace misconceptions with more informed, solidly based understanding. For instance, learners may revise their initial drawings of groundwater flow using their new knowledge of water tables and aquifers.

Essential components of this phase include:
1. Allowing ample time for learners to articulate, discuss and compare new ideas.
2. Asking individuals to be aware of the changes in their understanding of concepts and terms. (The water table concept and definition of aquifer are frequently misunderstood ideas.)

7. Extensions: applying and extending information to related areas. New information is applied to other situations to aid in the assimilation of knowledge. Questions arising during the activity may be discussed during closure and provide areas for further investigation. Note that the first suggestion in each Extension section is another activity from the curriculum (this gives order to the curriculum).

Evaluation

At the completion of any activity or curriculum, there are three types of evaluation that take place. First, the teacher determines if the activities interested the participants and added to their knowledge. A written record of comments and questions is a good technique for post-evaluation. Often, the questions learners ask indicate more about their knowledge than the statements they make.

Next, the participants evaluate their experience. A group discussion or simple writing assignment can illustrate how initial ideas were challenged and changed by the activity. Finally, the teachers record their observations of the process and total experience. Notes on what worked well are just as important as notes on what needs improvement

Teaching Tips for Incorporating Critical Thinking Skills

Each learner brings to a new idea preconceptions about how the world works. Research has shown that overcoming these biases is very difficult for children and adults. Science educators are developing strategies to facilitate the understanding and acceptance of new ideas. Summarized below are teaching suggestions based on research findings that were applied to the development of the Coastal Watersheds At Bay curriculum.

1. Concentrate on fewer, rather than more, concepts. Explore ideas from many points of view, with sufficient time for discussion, questions and application.

2. Encourage learners to observe, question, try out ideas, and make mistakes. Follow-up with discussion, analysis and communication of their thoughts and discoveries.

3. Understand a concept thoroughly; do each activity before presenting it to others.

4. Relate new concept(s) directly to an everyday experience or phenomenon. Activity based models and analogies are an effective "short cut" to connect familiar ideas to new or unfamiliar ideas - concrete to abstract.

5. Learning is not a spontaneous consequence of exploring with "hands-on" activities. True learning occurs when the participant is able to verbalize ideas and theories and support them with statements based on the results and conclusions of the exploration and discovery. A good educator is active and alert during all phases of the learning cycle, employing strategies of probing, focusing, and discussion.

6. Thinking about how we think and learn is an indispensable step for all participants. Both educators and learners use thinking strategies as tools to unlock and examine problems and arrive at solutions.

Age Levels

The "Coastal Watersheds At Bay" curriculum was developed with families in mind. The WBNERR staff and Education Advisory Committee wished to engage people of different ages and interests in an educational and fun activity. The curriculum is intended for ages ten (grade four) to adult because most of the concepts and activities require some abstract thinking skills. An age recommendation is included in each activity; some of the activities are better suited to eleven or twelve year-olds because they include math skills beyond the experience of many fourth graders. The curriculum may be modified to younger children as well. For example, the Watershed Model Construction Activity can be geared to kindergarten children by modifying the vocabulary and shortening the activity. Younger children, in particular, benefit from hands-on activities that combine discussion with physical participation in an activity.

The curriculum incorporates hands-on activities to link the familiar (concrete) to the unfamiliar (abstract), making the unknown easier to understand and assimilate. Although some participants may have a more sophisticated understanding than others, learners of all ages and levels will come away with a clearer understanding of how their watershed works, and be able to make more informed decisions to protect this resource.

List of Materials

The curriculum is intended for individuals who have participated in a training session. Training is available to teachers and members of community groups who wish to use the curriculum in conjunction with school or community activities .

Those who use this curriculum on their own need the following:

1. Supplied with the Curriculum:
   Worksheets to accompany each activity (to be photocopied by instructors).
   Background information sheets for instructors.

Detailed descriptions of activities.
Materials list for each activity.

2. Available on loan from Waquoit Bay Research Reserve, Barnstable County Extension, and 4-H Farley Education Center:
   Table top model kit for the groundwater activities:
   15 plastic vials (6 cm3) containing clean, coarse beach sand
   20 pipettes
   5 plastic containers (2" x 5" x 2") containing polished pebbles to represent aquifers
   5 turkey basters
   5 sponges
   5 clear measuring cups
   (teachers provide food coloring, Kool-Aid powder and soil samples)
   Additional materials kit:
   Posters and resource books
   Cassette tape of water sounds, "A Country Stream" for guided imagery
   Copies of the "Raindrop Journey"

3. Available for loan from the Waquoit Bay Research Reserve:
   Field Kit:
   Models and plastic for 3-D watershed model construction
   Watering can
   Pail
   Trowels
   Laminated GIS maps
   Water Quality Sampling Kits
   Clipboards

4. Teachers will need to provide:
   Food coloring
   Table salt
   Sugar-free grape Kool-Aid
   Tape recorder
   Cut soda bottles and soil samples for Permeability and Porosity of Different Soil Types Activity.

Suggested Activity Sequences

You may use the "Coastal Watersheds At Bay" curriculum in many ways. We suggest three sequences of activities but you are encouraged to fit individual activities into other curricula you are using or to use this curriculum as a whole unit on groundwater and watershed dynamics. At the Waquoit Bay Reserve, instructors use the curriculum in many ways, selecting activities they are most comfortable presenting to groups, or choosing activities to cover particular concepts at a given time and place.

Three activity sequences are suggested below: (1) The Watershed Field Trip, (2) Geography and Geology of the Watershed, and (3) Water Use and Pollution. The Watershed Field Trip option is most often used at the Waquoit Bay Reserve.

Watershed Field Trip

The aim of the Watershed Field Trip is to provide the opportunity for first-hand observations to make a real-life connection to the "object" of the study by bringing participants to the watershed itself. A map of the Waquoit Bay Watershed is provided on the back of the "Raindrop Journey." Numbered stops indicate where many of the activities take place. The activity is expected to take five hours, including the lab section, a lunch break and the actual field trip. Alternatively, this activity can be divided over a number of days.

If your field trip takes place in a different watershed, prepare maps of your area. Field trips in other watersheds may take more or less time.

I. Raindrop Journey

Participants experience moving through the watershed in the form of a raindrop. This imaginary trip opens their minds to the possible encounters a simple raindrop could have here on Cape Cod.

II. Personal Daily Water Use

Participants list how they use water and how much they use each day. They examine how their uses might pollute groundwater and threaten the availability of water on the Cape. (Begins the "lab" section)

III. Groundwater Cross-Section

The group identifies their preconceptions of how water exists and moves in the ground, by filling in a diagram with their own ideas. (Lab)

IV. Groundwater Models Parts II-IV

Using hands-on models, the group clarifies their conceptions of groundwater and how land uses can pollute and deplete groundwater resources. (Lab)

V. Placing the Watershed in a Geographic Context

Participants look at the location of their watershed and define the kinds of land uses, natural and human, that affect groundwater movement and quality. (Lab)

VI. Land Use Survey

On a ride through the watershed, the group records the kinds of land uses they observe and discusses the impacts each may have on groundwater. The information is used in the succeeding activity to create a model of the watershed. (Begins the field trip)

VII. Watershed Model Construction

Using the information from the previous activity, participants build a model of their watershed from the ground up. By operating the model, they can observe how land uses impact groundwater in the watershed. (Field trip)

VIII. Land Use Planning

The participants plan land use patterns for their town. Can they come up with a plan that will not have an impact on the environment? (Definitely not, but they will see that informed decision-making greatly increases our ability to protect resources. (Field trip)

IX. Water Quality Testing

The participants will perform dissolved oxygen and nitrogen (nitrate or ammonium) tests on a water sample from their watershed. The data and background information from the instructor may suggest what kinds of land uses are affecting the water. (Field trip)

Geology And Geography Of The Watershed

Focusing on human land uses and groundwater dynamics within the context of geology and geography provides a unique perspective on watershed dynamics. This sequence can be done inside although some activities are suitable to do outside. The entire sequence takes about three hours.

I. Groundwater Cross-Section

The group identifies their preconceptions of how water exists and moves in the ground, by filling in a diagram with their own ideas. (Lab)

II. Groundwater Models- Parts I - V

Use of several different hands-on models allow the participants to clarify their understanding of groundwater, within the context of geology.

III. Permeability and Porosity of Different Soil Types

Testing different types of soil in the watershed reveals how substrate may influence the movement of groundwater and therefore the pollution rate of groundwater.

IV. Using Well Measurements to Picture the Water Table

Creating a profile of land and water table levels above sea level describes how well measurements can define the boundaries of a watershed.

V. Placing the Watershed In A Geographic Context

Using maps, participants place their watershed in the world's water system.

VI. Land Use Survey

On a ride through the watershed, participants record the kinds of land uses they observe and discuss the impacts each may have on groundwater. The information is used in the succeeding activity to create a model of the watershed. (Begins the field trip)

The indoor version of this activity uses a map of land uses in your area. Small groups may follow particular routes and record the land uses they observe on the map. The land uses in their watershed have direct bearing on the groundwater quality.

VIII. Land Use Planning

The participants plan land use patterns for their town. Can they come up with a plan that will not have an impact on the environment? (Definitely not, but they will see that informed decision-making greatly increases our ability to protect resources. (Field trip)

Water Uses and Pollution

Participants analyze their own water use, the water uses of the community and the impacts of land uses on water resources. This sequence takes about five hours.

I. Raindrop Journey

The participants take an imaginary trip down the watershed and discover the many encounters one tiny raindrop may have as it moves through the watershed and the water cycle.

II. Personal Daily Water Use

Participants list how they use water and how much they use each day. They examine how their uses might pollute groundwater and threaten the availability of water on the Cape.

III. Land Use Survey

On a ride through the watershed, participants record the kinds of land uses they observe and discuss the impacts each may have on groundwater. The information is used in the succeeding activity to create a model of the watershed.

An indoor version of this activity could employ a map of land uses in your area. Groups may follow particular routes and note the land uses they observe on the map. The land uses in their watershed have direct bearing on groundwater quality.

IV. Watershed Model Construction

Participants build a model of their watershed from the ground up. By operating the model, they can observe how land uses impact groundwater in the watershed.

V. Land Use Planning

The participants plan land use patterns for their town. Can they come up with a plan that will not have an impact on the environment? (Definitely not, but they will see that informed decision-making greatly increases one's ability to protect resources.

VI. Water Quality Testing

What results might you expect from determining dissolved oxygen, nitrate or ammonium concentrations, considering the types of land use in your watershed area?

VII. Plotting Dissolved Oxygen Concentrations

Fish kills are a phenomenon common to some embayments in watersheds. This exercise takes students through the events (a combination of nutrient loading and poor weather conditions) that lead to a fish kill.

VIII. Algal Growth Experiment

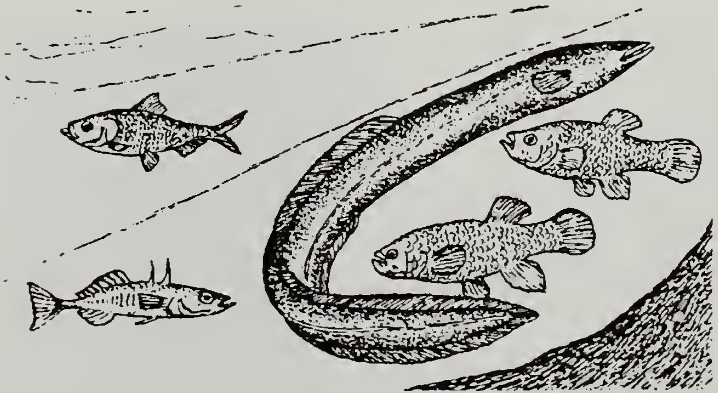
Participation in an ongoing experiment provides the opportunity to use the scientific method and connect the role of the researcher to land use planning.

IX. Critiquing the Press

Participants use their knowledge of nutrient loading to write their own press release describing the events leading to a fish kill.

Part II

A Primer for Educators



Geology and the Watershed

All of Cape Cod, including the Waquoit Bay watershed,* formed during the advance and retreat of a continental glacier between 25,000 and 15,000 years ago (Oldale, 1991). This was at the end of the period called the Ice Age when the global climate was very much colder than it is today. The major effect of the cold climate was that snow that fell in central and eastern Canada did not melt during the summer but instead accumulated and packed down into ice. This continent-sized layer of ice is the glacier that formed the Cape. It did so because ice, although it seems hard in ice cube sized pieces, actually can flow. So this ice began to flow south and east away from the area of greatest accumulation and then down the gentle regional slope toward the sea.

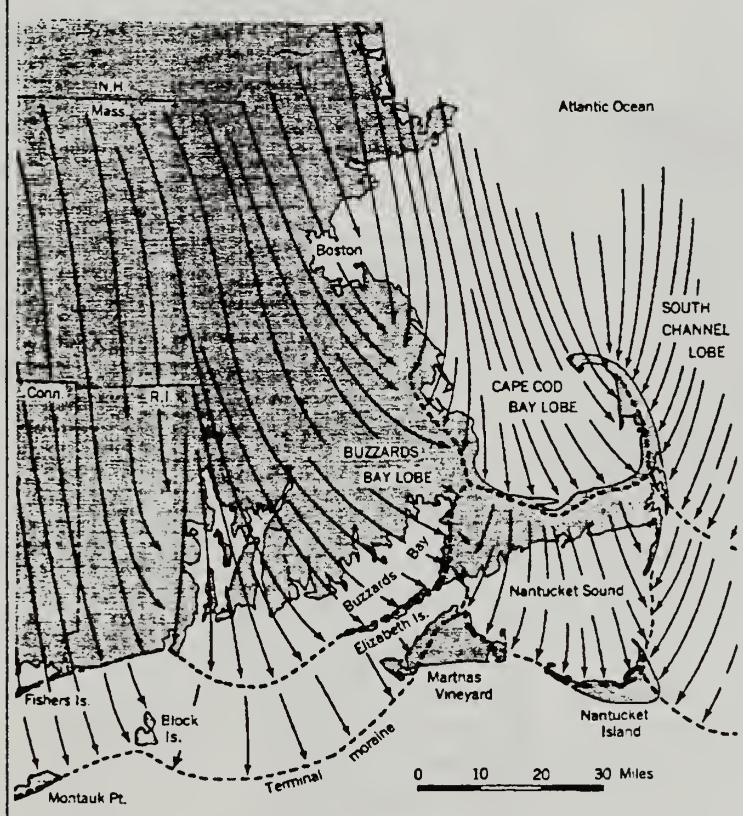


Figure 1. Map of SE New England showing the directions of ice flow during the Wisconsin Stage as well as the two positions of ice standstill (dashed lines). (Based on a map by Woodworth and Wigglesworth, 1934.)

As glaciers move they act like sandpaper, scraping and smoothing the rock beneath them, and like bulldozers, pushing everything loose along with them. Of course, as the glacier moved south it found warmer weather, so the front edge of the glacier melted. For a time the melting reached equilibrium with the glacial movement so the front of the glacier remained at about the same place for thousands of years, depositing rocks and sand and gravel in hills called moraines. As the glacier ice melted, it carried sand and gravel away from the front of the glacier and deposited it on the gently sloping continental slope beyond the front of the glacier. This area, called outwash or outwash plains, forms much of the Cape (Figs. 1 and 2).

Blocks of ice buried in the outwash left depressions when they melted, forming kettle hole ponds, one of the very clear indicators of glacial activity. Well known examples include Fresh Pond, Johns Pond, and Ashumet Pond. The scattered kettle holes give the area a pitted look, and regions of this kind are therefore called pitted outwash plains.

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*Technically, a watershed is the area from which water flows over the surface of the ground to a particular place. In Southeastern Massachusetts, however, the ground is made up of coarse, sandy soils, deposited during the glacial retreat about 15,000 - 12,000 years ago (Oldale, 1991). Water travels relatively easily through the pores between these sand grains, and most of the water flow on Cape Cod therefore occurs under the ground. Because most of the flow within the region that contributes water to Waquoit Bay occurs underground, this area, strictly speaking, is not a "watershed." For purposes of simplicity, we refer to it as a watershed and more or less ignore this distinction.

Water flows easily through the spaces between the sand grains in Cape Cod soils, and this accounts for many of the basic processes and problems that we find in the Waquoit Bay watershed and other watersheds that lie in pitted outwash plains on Cape Cod. Therefore, understanding how water flows through a pitted outwash plain helps us understand much of what we see in the estuary.

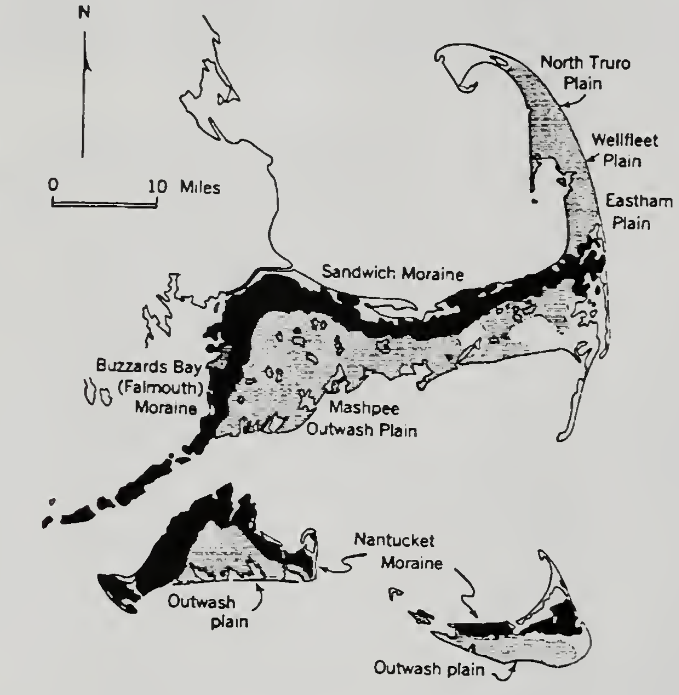


Figure 2. Moraines (solid black) and outwash plains (shaded) of Cape Cod, Marthas Vineyard and Nantucket Sound. (Based on geologic maps of Woodworth and Wigglesworth, 1934.)

Fifty percent of the water falling on an average watershed flows over the surface; the other 50% seeps, or percolates, into the ground. However, in most Cape Cod watersheds, which lie on pitted outwash plains, there is little surface runoff. Up to 90% of the annual rain and snowfall (42-44 inches) percolates into the ground, and 10% flows over the surface into streams and ponds. Water that seeps into the ground continues to percolate downward until it reaches an impermeable layer (i.e., clay or bedrock). The area above this is called the zone of saturation, where all pore spaces are filled with water. The top of the zone of saturation is called the water table, and the saturated sediment is called an aquifer. When the water reaches an impermeable layer it flows slowly sideways under the pressure of the water above it.

Hundreds of springs trickling from the banks of Red Brook River, the Childs River, and the Quashnet River illustrate the widespread movement of underground water in the Waquoit Bay watershed. The streams, like most on Cape Cod, are not fed primarily by direct rainfall but by groundwater that emerges where the elevation of the land drops below the level of the water table. The flow of water through the region plays a large role in determining the abundance and distribution of organisms in the watershed. Most organisms are sensitive both to the quantity of water available and its quality.

Because the spaces between the sediment grains in outwash plains are large, groundwater travels through them relatively quickly, at a speed of about two feet per day. In watersheds composed of finer grained sediments or bedrock, groundwater travels more slowly. Unfortunately, the same characteristics that facilitate relatively swift flows and plentiful storage of water through the outwash plain increase the potential for pollutants to enter and move through the groundwater system.

The Waquoit Bay Watershed

A watershed is a region in which all precipitation flows to a common place. Thus the Waquoit Bay watershed is the region in which all precipitation flows to Waquoit Bay. Water falling on the ground outside of the Waquoit Bay watershed flows to another drainage basin. People often say that a particular river or bay drains a watershed; the watershed is the region that the bay drains. Watersheds occur on different scales. The North American continental divide separates two large scale watersheds. Water flowing on one side of the divide flows to the Pacific; water falling on the other side of the divide flows to the East. Within the Waquoit Bay watershed, we can define subwatersheds; precipitation on one area flows to the Child's River; precipitation on another area flows into Sage Lot Pond. Since the Child's River and Sage Lot Pond flow into Waquoit Bay, these subwatersheds are part of the Waquoit Bay watershed. We commonly discuss seven subwatersheds of the Waquoit Bay watershed (Fig. 3).

Two forces determine the flow of water from one place to another: gravity and the pressure of adjacent or overlying water. Underground, the flow of water can be complicated by deposits of impermeable clay or rock that block its path, forcing it in one direction or another, just as a dam can alter the flow of water on the surface.

In Sandwich, near the upper end of the Waquoit Bay watershed, impermeable bedrock lies near the surface. Thus, groundwater cannot penetrate deeply and, upon reaching the bedrock, begins to flow laterally, downhill, towards the bay. Eastward from Sandwich, the bedrock falls off steeply to a depth of 200-400 feet below the surface. Saltwater intrudes into these sediments and forms a layer upon which the less dense freshwater floats as it continues to flow towards the bay.

All of Cape Cod features estuarine systems. Estuaries are areas where the land meets the sea and freshwater flows into salt water. A mixture of fresh and salt water is called brackish water. As freshwater streams, rivers and ponds approach the ocean, their salinity increases. The freshwater floats on the denser saltwater creating a freshwater "lens." These same dynamics exist underground. The entire aquifer of Cape Cod is composed of a freshwater lens floating above saltwater.

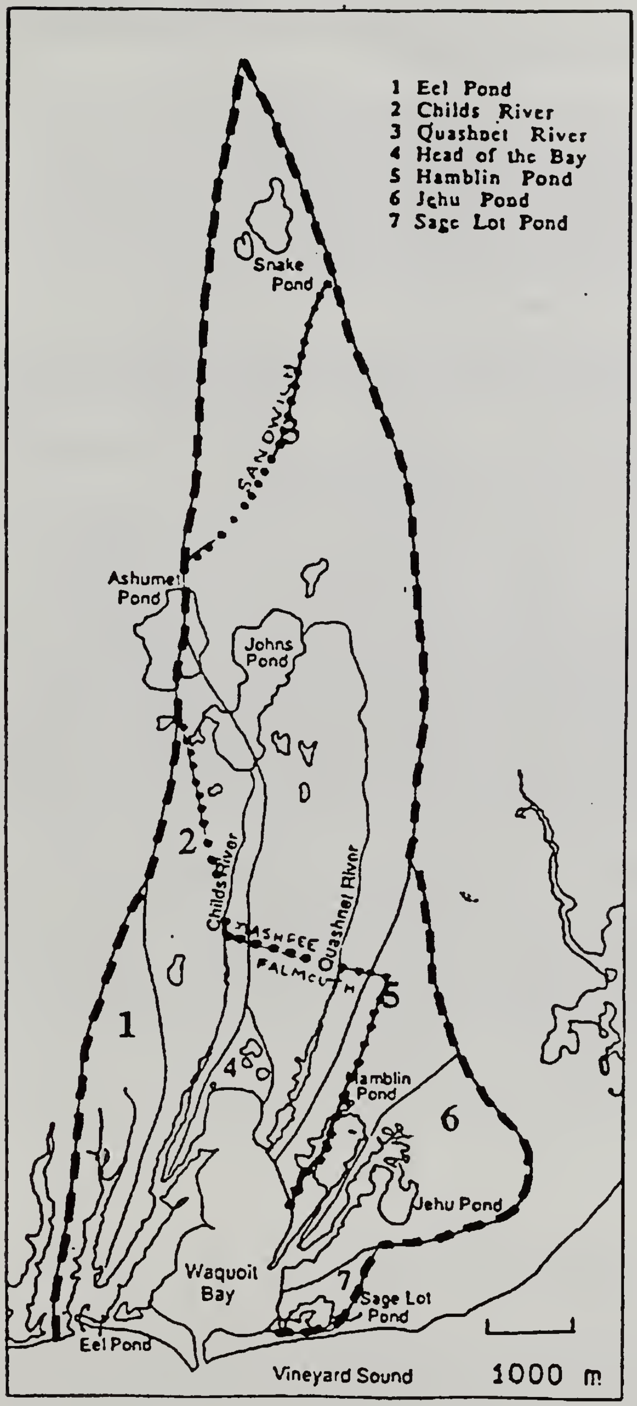


Figure 3. The seven subwatersheds of the Waquoit Bay Watershed. Data fromthe Waquoit Bay Land Margin Ecosystem Research project.

Further inland, the saltwater lies deeper in the ground. Heavy well pumping and overuse of freshwater can deplete the freshwater and eventually draw saltwater into what once was a freshwater aquifer. This sometimes occurs on the Cape.

The Direction of Groundwater Flow

To determine the direction of groundwater flow in coastal areas, geologists need to know the height of the water table above sea level at a number of different sites. As on the surface, water under the ground flows from higher elevations to lower elevations. For groundwater the elevation that counts is not the elevation of the surface of the land but the elevation of the water table. To determine the height of the water table above sea level in a particular place it is necessary to measure the depth of the water table in a well.

By itself, the depth of the water table in the well does not indicate the height of the water table above sea level; it marks the depth of the water table under the surface of the land. However, we can usually find the height of the land above sea level. With these two pieces of information (depth of the water in the well and height of the land above sea level), it is a simple matter to calculate the elevation of the water table relative to sea level (height of the land minus the level of the water).

To determine the direction of groundwater flow, the elevation of the water table in a number of locations must be calculated. Consider water flowing over the surface of the ground. With only a single elevation point, there is no way to know if the ground slopes off steeply in one direction or is flat for miles around. Therefore, knowing the elevation at a single point indicates nothing about water flow. Geologists use the information from a number of wells to create a picture of the water table and determine the boundaries of a watershed (Fig. 4). If the water table at well 4 is higher (relative to sea level) than the water table at a nearby well (well 3), the groundwater is flowing from well 4 to well 3, just as water flows down hill on the surface of the ground. On the other side of well 3 is a well at a lower water table level (well 2) So, the groundwater must be flowing from well 4 to well 3 to well 2.

To understand how this picture of a water table enables geologists to define the boundaries of a watershed, consider a mountain ridge. Water flows downhill off both sides of the ridge. Look at well 5 on the other side of well 4. If the water table in well 5 is lower than that in well 4, the groundwater flows from well 4 to well 5 as well as from well 4 to well 3. The groundwater is at a high point in well 4, flowing off in two directions, just as it does off a mountain ridge. Well 4 must be located between two watersheds.

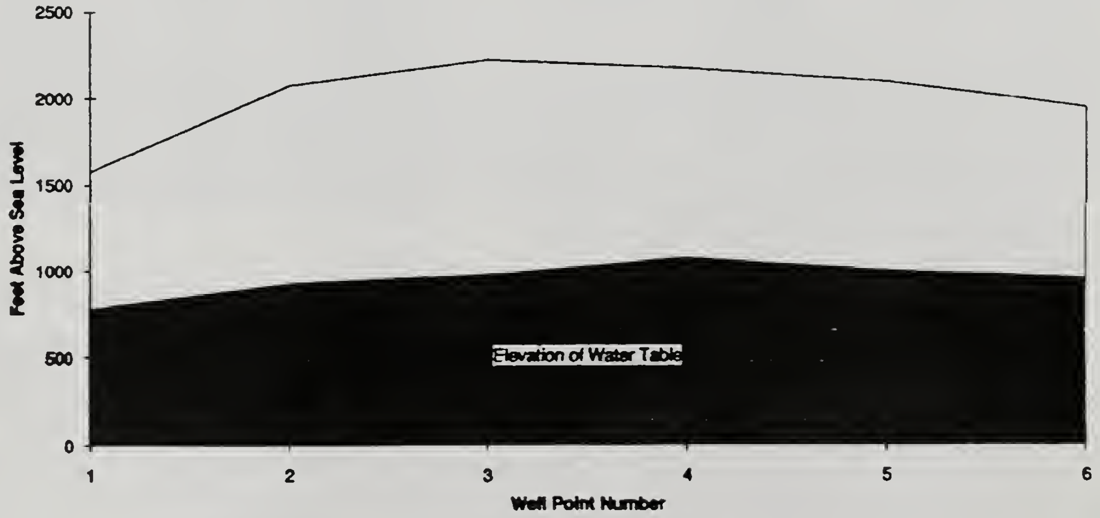


Figure 4. Using well point measurements to determine groundwater flow and the boundaries of a watershed.

Eutrophication

Plants need nitrogen and phosphorus in order to function and grow. From a plant's point of view, these elements are nutrients. Up to a point, adding nitrogen and phosphorus can make plants grow faster. That is why these elements are the major ingredients in fertilizers. But many plants have an upper limit on the rate at which they can use these nutrients. If nutrients are supplied at a faster rate, some plants may suffer while a very few species that can use the nutrients to grow and reproduce very rapidly may overwhelm the ecosystem. Nutrients get into a watershed from a variety of sources, some natural, some man-made. If an area is relatively undeveloped, most of the nutrients enter the watershed from natural sources, such as precipitation. In an urbanized watershed man-made sources of nutrients, such as septic systems and lawn fertilizer, may completely outweigh natural sources (Valiela and Costa, 1988).

We describe lakes, ponds, streams and bays which have more nutrients than the natural system can use as eutrophic. The ecosystems in these fertilized water bodies exhibit marked differences from comparable non-eutrophic areas. Eutrophic systems tend to have fewer varieties of plants and animals and to be less stable than non-eutrophic systems.

The most important nutrients are nitrogen and phosphorus. In freshwater systems, the growth of algae and plants usually is limited by the amount of phosphorus dissolved in the water; that is, the plants grow at a rate limited by the input of phosphorus. In brackish and marine ecosystems, the amount of nitrogen available often limits how fast plants, algae, and phytoplankton can grow. Nitrogen is an element important for life because it is an essential component of several classes of biologically important molecules including proteins, nucleic acids (DNA, RNA), and in the case of plants, pigment molecules. Mammals (including humans) obtain their nitrogen by eating; we digest nitrogen-containing molecules and reuse the nitrogen to build new molecules. Plants and algae absorb nitrogen from the surrounding environment.

Rainwater from fertilized fields and septic effluent percolate down through the soil to the water table, carrying nitrogen with them. Because water moves freely in the coarse sediments of pitted outwash plains, a particular pond or stream receives nitrogen-laden effluent not only from houses bordering it, but from all the houses in the watershed. Eventually, all this nutrient-laden groundwater reaches the coast. In recent years, as more and more nitrogen has been added to waters entering Waquoit Bay, populations of several species of algae have exploded.

Symptoms of Eutrophication

Eutrophication occurs when a body of water receives more nitrogen and phosphorus than it can use in its natural balance. Certain algae react to the influx of nutrients with population explosions. In Waquoit Bay, *Gracilaria* and *Cladophora*, have responded to the extra nitrogen by multiplying at an increased rate.

These algae form large mats near the bottom of the estuary. During the summer, as the mats accumulate oxygen in the process of photosynthesis, many float to the surface as a small indication of what is going on underwater. These algae affect the bay's ecosystem in a number of ways. First, the mats may prevent light from reaching the eelgrass that grows on the bottom of the bay. The eelgrass serves as a nursery and feeding ground for many species of fish, including winter flounder, and as a surface upon which scallop larvae settle. So, any decline in the eelgrass populations can affect other parts of the ecosystem. A usually unobserved but equally important effect of the large algal populations are serious changes in the concentration of dissolved oxygen (D.O.) in the bay.

Dissolved oxygen in water is not the oxygen that is bonded to hydrogen to form water (H_2O). Oxygen molecules (0_2), consisting of two oxygen atoms bonded to each other, are found between water molecules. This can be difficult to visualize because we are used to thinking of oxygen in the air, but a few everyday experiences make the idea easier to grasp. Consider carbonated water; this is simply water with carbon dioxide molecules (CO_2) sliding in between the water molecules. When we dissolve sugar in water, the sugar molecules separate from each other and slide between the water molecules. So, when we talk about dissolved oxygen in water, we are referring to the oxygen molecules that are sliding between the water molecules. A healthy water body contains about 6 - 10 parts per million oxygen (that is 6 - 10 molecules of oxygen per million molecules of water).

The algae affect dissolved oxygen concentrations because, like all plants, they photosynthesize during the day. Photosynthesis is the production of sugar, from carbon dioxide and water (synthesis), using energy captured from light (photo). Oxygen is a byproduct of this process. During the day, algae produce oxygen, which dissolves in the water.

At night, the algae respire. Respiration is the opposite of photosynthesis; it is the production of energy (and carbon dioxide and water as byproducts) by burning sugar (reacting it with oxygen). This is what animals, including humans, do all the time, and it is the reason we need oxygen. Without oxygen, we cannot efficiently breakdown glucose to produce energy. Many people do not realize that at night plants take in oxygen to break down the sugar that they produce during the day. Because there is so much algae in the bay, the algae mat produces a lot of oxygen during the day (through photosynthesis) and consumes a lot of oxygen at night (through respiration), so there are wide swings in the oxygen concentrations between morning and evening (D'Avanzo, pers. comm., 1991) (Fig. 5).

On cloudy days, the algae receive relatively little light so they cannot photosynthesize as much and produce less oxygen than they would on sunny days. At night, they respire as they do every night. A series of cloudy days leads to a drop in oxygen production, but oxygen consumption rates remain the

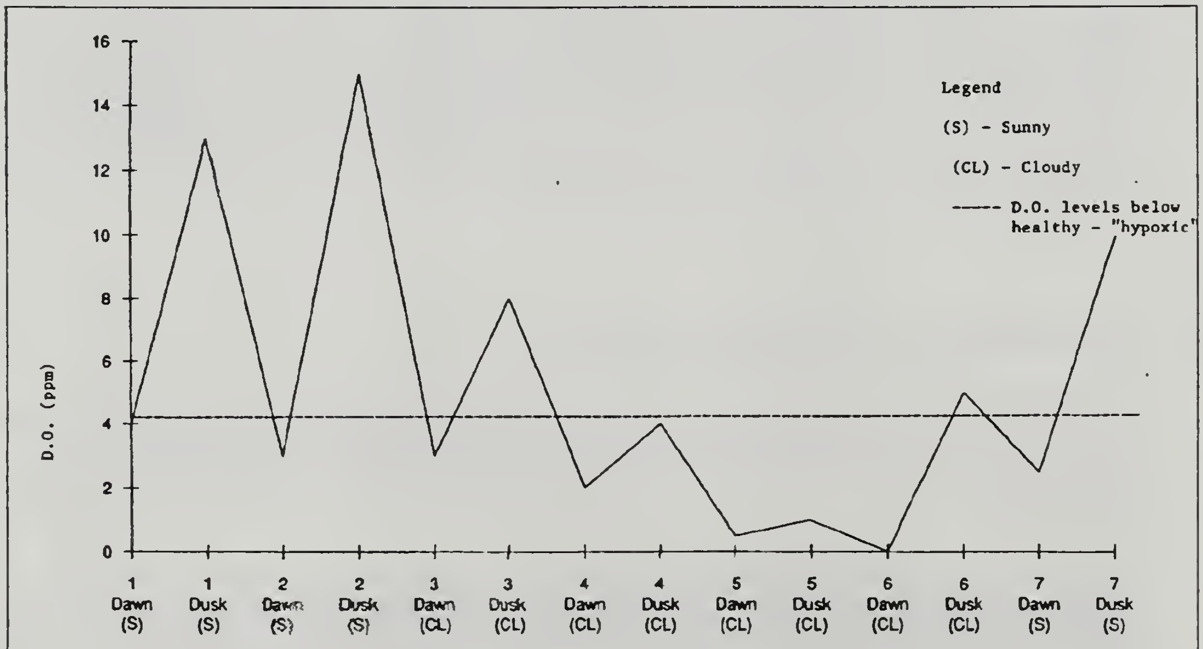


Figure 5. Dissolved oxygen levels at the bottom of Waquoit Bay.

same. After a series of cloudy days, the algae can use up all the dissolved oxygen and dissolved oxygen levels fall to zero in the early morning.

Most animals living in the bay cannot survive for long without oxygen. When oxygen levels fall below 4 parts per million (ppm), fish begin to swim close to the surface where oxygen concentrations are slightly higher. Eventually, fish and shellfish try to climb out of the water onto beaches. If oxygen levels stay low for a period of hours, thousands of fish and shellfish die.

Fish Kills

Respiration by algae is not the sole determinant of dissolved oxygen concentrations. Temperature and seasonal weather patterns affect dissolved oxygen concentrations. Warm water holds less oxygen than colder water. Seasonal weather patterns, such as unusually warm springs or cool summers, affect water temperatures and algal growth rates. Respiration rates of animals and plants that live in water are directly related to water temperature (Peckol, pers. comm., 1992). Fish kills are likely to happen after a series of cloudy days in the late summer in response to all of these factors building up.

For example, in the summer of 1988 a massive fish kill occurred In Waquoit Bay. A long hot spring and summer warmed the water, which decreased the amount of O_2 dissolved in the water. The algal biomass had reached its peak at the same time the weather pattern changed to a series of cloudy days. After a few days, the dissolved oxygen was depleted and animals began to die in large numbers. A meter-wide band of dead blue crabs, eels, winter flounder and shrimp washed up on the shore at the head of Waquoit Bay. By contrast, in 1991 the early spring was sunny and hot and the algal biomass peaked earlier in the growing season than in the previous summer. When a series of cloudy days occurred in the late summer, the waters became hypoxic, or very low in dissolved oxygen (3 ppm dissolved oxygen), but not anoxic (0 ppm dissolved oxygen). The biomass of algae was not great enough to totally deplete the dissolved oxygen. Fish kills were anticipated in 1992, but a cool summer kept water temperatures down and dissolved oxygen levels fairly even.

Since algae are naturally-occurring plants in aquatic systems, the question is sometimes asked whether land use actually contributes to the excessive growth of these plants There is good correlation of algal blooms and fish kills with impacts of human land use. It is not possible to prove at the moment that human land use is the cause of fish kills.

Algal Physiology

Are algae nitrogen-limited in the Bay? It is interesting to look at how researchers study this question, testing hypotheses and increasing their understanding of the system. To illustrate, consider two experiments Dr. Paulette Peckol and her group have conducted on algal growth.

In one experiment, the researchers tied small bags of fertilizer to mats of a particular species of algae (*Gracilaria*) and left other mats alone. They measured the growth rates of both the fertilized and control plots at different times of the year. During the summer when algae grow fastest, the fertilized sites grew at least 50% faster than control sites (Fig. 6). These experiments established that algae in Waquoit Bay are, in fact, nitrogen limited (the main factor limiting their growth is the amount of nitrogen available).

The second experiment examined the relative abundance of two species of opportunistic algae, *Cladophora* and *Gracilaria* that inhabit three subwatersheds of the Waquoit Bay watershed.

Groundwater in the heavily developed subwatershed surrounding the Childs River has a high concentration of nitrogen. Likewise, groundwater in the moderately developed Quashnet River subwatershed has an intermediate concentration of nitrogen. Last, the Sage Lot Pond subwatershed is in a state park and has not been developed at all; the groundwater there has very low concentrations of nitrogen. We would therefore expect algae growing where the Childs River empties into Waquoit Bay to grow fast, algae growing where the Quashnet River empties into the bay to grow more slowly, and algae growing in Sage Lot to grow even more slowly. Results of the study confirm this hypothesis and indicate that nitrogen is the key nutrient controlling the growth of algae in Waquoit Bay (Fig. 7).

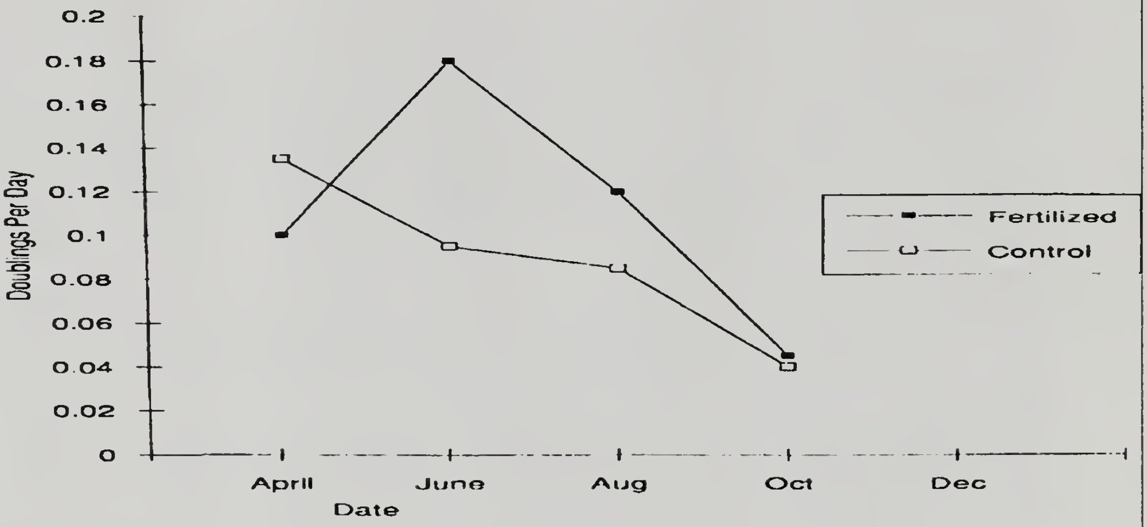


Figure 6. Growth rates of fertilized and control algae. Typically growth rates of seaweeds are reported as doublings per day, defined as the percentage of the change required to double the biomass in one day.

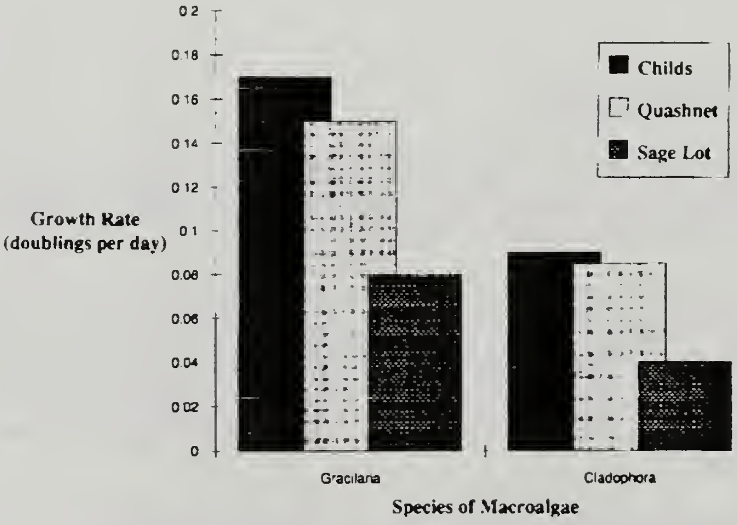
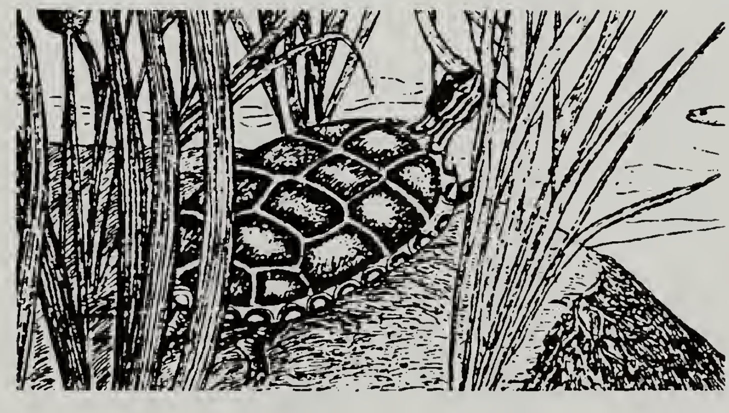


Figure 7. Growth rates of macroalgae in 3 subestuaries of Waquoit Bay (August 1990).

Part III

Activities



The Water Cycle

Activity: The Raindrop Journey

Introduction

The "Raindrop Journey" is exactly that: a trip down a watershed in the form of a raindrop. Written by John F. Waters, the "Raindrop Journey" uses guided imagery to help readers imagine what a tiny drop of water experiences as it moves through the water cycle, from land to sea to air and on and on.

The "Raindrop Journey," an important part of other curricula developed by Barbara Waters, begins this curriculum as well. Shaded and lettered areas in the text act as a "concept" guide to the various activities. Many correspond to specific activities in the "Coastal Watersheds At Bay" curriculum as well. The concept areas are focal points for discussion and thought and prepare participants to think about water beneath the ground and the many ways we use this resource. Recognizing the human impact on a resource encourages citizen awareness and therefore more informed decision making. The following list shows the letter of the concept area and the associated activity.

Activity	Concept
Personal Daily Water Use	G
Watershed Cross-Section	G
Groundwater Models	
Part I: Aeration and Saturation	A
Part II: Permeability, Porosity and Percolation	A
Part III: Plumes	B
Part IV: Water Tables and Aquifers	E,G
Part V: Defining the Bottom of the Aquifer	H
Using Well Measurements to Picture the Water Table G	
Permeability and Porosity of Different soil Types	G
Placing The Watershed in a Geographic Context	B
Land Use Survey	C
Watershed Model Construction	C
Land Use Planning	C,D,E
Water Quality Testing	I
Plotting Dissolved Oxygen Concentrations	I
Algal Growth Experiment	I
Critiquing the Press	J

To make the "Raindrop Journey" experience most interesting and effective, follow the "Steps Toward Effective Use of Guided Imagery" found in Project Aquatic Wild (p.44) and reprinted here. The "Raindrop Journey" ties together familiar, concrete experiences with the abstract ideas that will be expanded upon in this curriculum. Enjoy the journey!

Ages: 10 -100

Goal:

To become aware of the many ways water moves through a watershed.

Summary:

1. Participants use guided imagery on a trip through the watershed in the form of a raindrop.

2. Participants will discuss the many encounters the raindrop has in the story.

Time, Place and Materials

This activity takes about 20 minutes. Have everyone use the bathroom first! The sounds of the "Country Stream" tend to inspire people. The activity works well indoors or outdoors. The following materials are needed:

***tape of water sounds, i.e., "Country Stream"**
***tape player**
***copies of the Raindrop Journey, one per person (in pocket of binder)**
***Steps Toward Effective Use Of Guided Imagery (for the instructor)**

Introduction and Motivation:

Follow steps 1-3 in Steps Toward Effective Use Of Guided Imagery.

Activity Procedure:

Follow steps 4-6 in Steps Toward Effective Use Of Guided Imagery. The instructor may read the narrative to the group, or group members may read passages.

Closure:

Follow step 7 in Steps Toward Effective Use Of Guided Imagery. Participants may wish to draw a particular scene from the story.

Extensions:

Any activity from "Coastal Watersheds At Bay"

Steps Toward Effective Use Of Guided Imagery.

1. Put aside all pens, pencils, books ,etc.

2. Instruct participants to sit in a comfortable, relaxed position with their eyes closed. Make sure no one is touching anyone else.

3. Wait to begin until you see a general state of relaxation.

4. Using a steady and paced reading or speaking style, begin the narrative. Allow time to create rich mental images. It takes about as much time to observe mental images as it does to carefully review actual physical settings.

5. After the reading, invite the participants to mentally review the images they saw. Again, allow ample time for an adequate visual review (at least one minute).

6. After the mental review, ask the participants to open their eyes.

7. Discuss the imagery in terms of the instructional purpose. In some cases, the imagery simply provides a visual review of a student's past experiences. At other times, you are providing stimuli for the students to create original images. In any case, there are no mistakes in mental images.

Understanding Water in the Ground

Activity: Personal Daily Water Use

Ages: 10 - 100

Goal:

To conceptualize daily water use, and encourage an appreciation of this resource.

Summary:

1. Participants estimate the amount of water they use each day and identify the ways they use water.

2. The group discusses ways to conserve water and why conservation is important.

Time, Place and Materials

This activity takes about 15 minutes to complete, and may be done anywhere.
Required Materials are:

- ***copies of the blank chart, "Categories of Water Use"**
- ***copies of the bar graph and pie chart showing water use**
- ***pens and pencils for everyone, (clipboards if outside)**

Introduction and Motivation:

Begin with some Fun Facts About Water and the Water Quiz (provided at the end of this Activity). Emphasize the importance of water for all living things.

Activity Procedure:

1. In pairs or small groups, participants categorize water use in their homes, workplace or school using the "Categories of Water Use" chart provided at the end of this activity. Students list categories across the top of the chart and their names down the side of the chart. Discussion : Consider merging some uses into one category, for example, place toilet and shower use under bathroom uses or dish washing and house cleaning under kitchen uses, etc. Suggest ideas but allow participants to choose the categories. Encourage creative thinking (car washing, filling up a pool, etc.).

2. Students estimate how much water they use in each category. Discussion: How many times a day do you use the toilet, (not just at home)? How many times a day do you wash your hands? How much water do you drink? How often do you take a bath or shower? Do you water a lawn or garden? How much laundry do you do in a week? (refer to "Fun Facts About Water" for gallon estimates for each type of water use.)

3. The groups sum water use per person per day and calculate the average consumption rate for the group. Total each category and calculate averages.

4. Groups report their averages to the class and compare differences. Or have each group graph their data; another set of averages may be calculated from this chart.

5. Show the group the bar graphs and pie charts illustrating average water consumption. Discussion: Are group members above average, average or below average consumers of water?. Rate the water use on a scale of 1-10, 1 being a below average consumer, and 10 being an above average consumer. Let them explain their personal ratings.

Closure:

Ask participants to brainstorm ways to decrease their daily consumption of water. Discussion: Do you have any tricks you use to conserve water at home?

Why is it important to conserve water? (Overuse of the resource could threaten the availability of water. Much of our water supply comes from groundwater, therefore pollution of groundwater via overuse of detergents, or dumping chemicals down the sink, like bleach or ammonia, greatly threatens the quality of drinking water.)

Extensions

1. Groundwater Cross-Section Activity develops awareness of where water comes from and where it goes after we use it.

2. Publish your own "Fun Facts and Conservation Hints for Water."

3. Create your own bar graphs and pie charts from the group results. Make this a computer activity if you have the resources.

4. Research water costs in your community. A typical water bill shows how much you pay per gallon. Call the local wastewater treatment plant to find out how many gallons they use in a day, a week, a year. Find out the costs of running the wastewater treatment plant.

Notes: Personal Daily Water Use is a perfect pre-activity to the Groundwater Cross-Section and Groundwater Models activities. It sets the stage for thinking about uses of water and how these uses may affect the watershed.

Fun Facts About Water

Did you know that:

There are 396 quintillion gallons of water on Earth? (369,820,250,000,000,000,000) Write this number for the group to see.

97% of the water on Earth is saltwater and therefore not directly available to man. 75% of the earth's freshwater is locked up in polar ice caps.

Americans use 700 billion gallons of water a day, directly or indirectly. That equals approximately 87 gallons per person per day. Let's try to break this down into specific activities for which we use water.

Drinking = 1 gallon
Cooking = 1 gallon
Flush of toilet = 5-7 gallons
Bathtub = 20 gallons
Shower per minute = 10 gallons, less if using a watersaver
Laundry = 25 gallons per load

Food production takes water, for example a loaf of bread requires 150 gallons from seed to supermarket. A quart of milk requires 233 gallons of water. 1,500 gallons of water are needed to transform a cotton seed into a cotton dress.

97% of a watermelon is water.
Loss of 15% of the water from our bodies is fatal.
We brush our teeth with the same water that dinosaurs drank.
Ultimately all of our water ends up in the ocean. This information is from Arana, 1990.

WATER QUIZ

1. How much of the Earth's surface is covered with water?
   (a) 30% (b) 50% (c) 70% (d) 90%

2. How much of the human body weight is water?
   (a) 30% (b) 50% (c) 70% (d) 90%

3. The evaporation of water from the leaves of plants is known as:
   (a) percolation (b) transpiration (c) precipitation (d) reincarnation

4. The average American uses how many gallons of water per day?
   (a) 15 (b) 54 (c) 87 (d) 104

5. Most of the drinking water on Cape Cod is obtained from:
   (a) fresh water lakes (b) desalinization of ocean water
   (c) above ground reservoir (d) wells that tap into an underground fresh water aquifer

6. Which of the following is the most biologically productive area?
   (a) Kansas wheatfield b) salt marsh
   (c) deep ocean (d) desert

7. An estuary is:
   (a) a place where saltwater and freshwater meet
   (b) a man-made lake where water is stored for human use
   (c) the scientific name for a blue crab
   (d) an instrument for measuring salinity

8. How many gallons are needed to produce one egg?
   (a) 0 (b) 1 (c) 50 (d) 120

9. How much does it cost for 1,000 gallons of water on Cape Cod?
   (a) $0.73 (b) $2.50 (c) $5.00 (d) $10.00

10. How much does it cost for the same amount in Chicago, Illinois?
    (a) $0.73 (b) $2.50 (c) $5.00 (d)$10.00

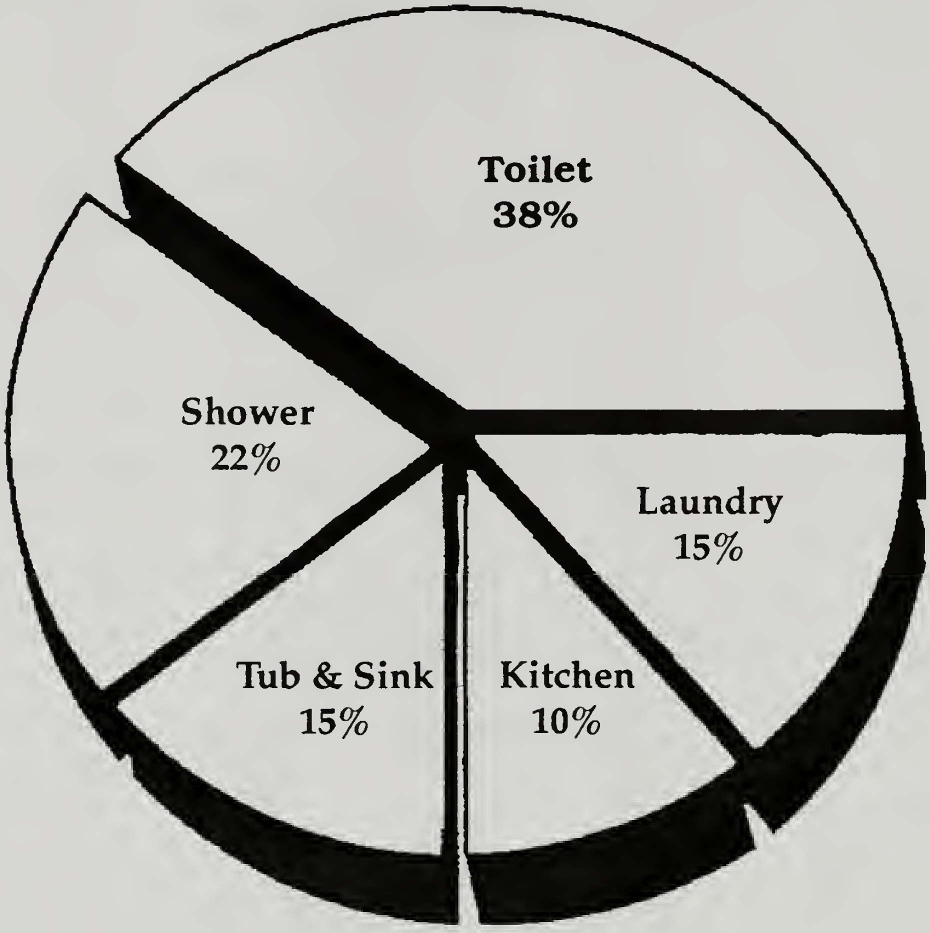
Answers: 1. (c);2. (c); 3. (b); 4. (c); 5. (d); 6. (b); 7.(a); 8. (d); 9. (b); 10. (a). This quiz is from Arana, 1990.

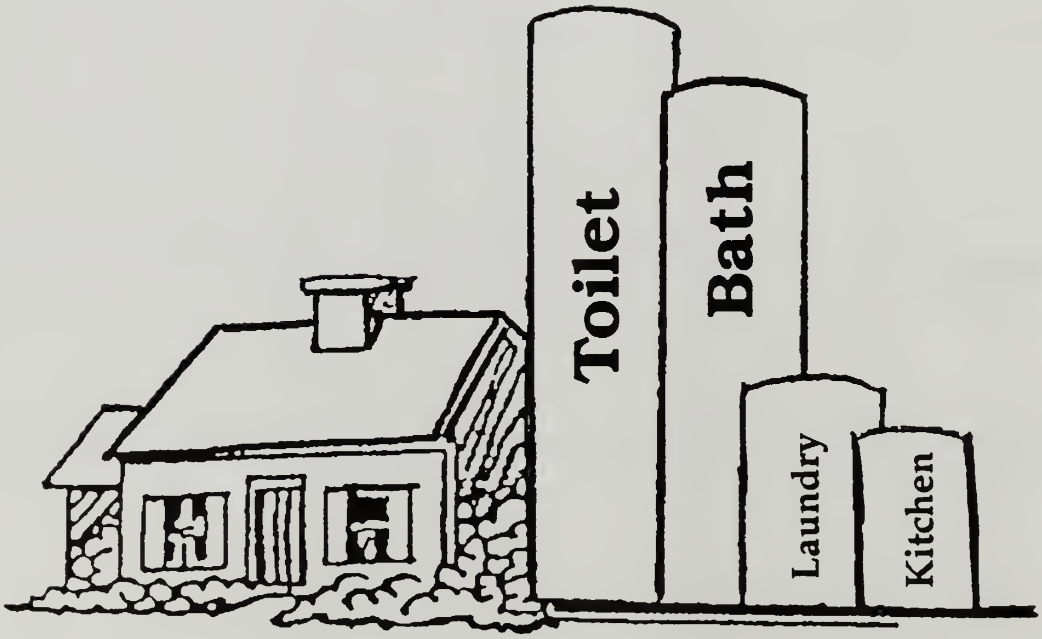
Daily Water Use

Water Use Categories

Group Members					
Average					

Water Use Charts





Activity: Groundwater Cross-Section

Ages: 10 - 100

Goal:

To clarify conceptions of water in the ground.

Summary:

1. Participants use the Groundwater Cross-Section diagram to create a general picture of water under and over the ground.

2. Learners illustrate the changes in their conceptions as they participate in the activity.

3. Peer interaction and teacher-facilitated discussion enhance understanding of ground and surface water.

Time, Place and Materials

Note: The Groundwater Cross-Section can be used as a "wrap-around" activity for Groundwater Model activities - a series of progressive hands-on experiences that clarify the participants' understanding of watershed dynamics. The Groundwater Cross-Section diagram records their preconceptions which they may alter as their ideas change. As their conceptions about groundwater become more accurate, new and more sophisticated questions on groundwater and watershed dynamics will be generated. Be sure all final pictures (at the completion of Groundwater Models) exhibit an accurate understanding of groundwater dynamics, as the visual depiction is what will remain in their minds.

*copies of the Groundwater Cross-Section diagram, one per person
*an easel with paper or a chalkboard for an enlarged drawing the group can see
*markers or chalk for the enlarged drawing
*pens and pencils for the participants

(Background Information: Primer for Educators, "Groundwater Pollution and Demography," p. II-9)

Introduction and Motivation:

Hand out the Groundwater Cross-Section diagram. Discussion: Most of the water on Cape Cod travels underground. Can anyone describe what groundwater looks like and how it moves? Ask the group to define groundwater. Ask them about the water they listed in the Personal Daily Water Use Activity-where did that water come from, where does it go?

Activity Procedure:

1. Refer to the diagram when talking about the following concepts. Discussion: Ask participants to identify what they see in the diagram. They can make up anything they want about the picture.

2. In pairs or small groups participants draw what they think groundwater looks like on the diagram and show how the different components on the diagram interact with the groundwater. Discussion: What is an aquifer, a water table? What is the difference between the two? Where do they lie underground? What do they look like? Note: This is not a test; rather it is an opportunity to identify

preconceptions and develop ideas about the dynamics of groundwater movement through trial and error. Allow time and encourage peer discussion.

3. What are some possible sources of pollution in the diagram. (runoff from paved areas, leachate from the town dump, septic effluent, acid rain, etc.)

4. What effects might the town well have on the surrounding groundwater? (It could lower the water table in a nearby pond, or pull pollutants into the town's water source.)

5. Participants use the depth scale on the right side of the diagram to illustrate how deep the water table is within the watershed system. Discussion: How deep does water travel under the ground? (Until it reaches an impermeable layer.) What forms the bottom of the water table? (On Cape Cod, first a salt water aquifer on top of which the freshwater floats; bedrock is found at around 300 ft. below the surface of the ground.) Where is the bottom of the water table?

6. Invite participants to come up to the chalkboard or easel and draw their ideas and explain them. Discussion: Allow the group to actively discuss their agreements, disagreements, thoughts, questions and comments about the dynamics of groundwater movement. The leader can steer the discussion toward those ideas that most closely represent the actual working dynamics of the watershed without giving away any secrets!

Closure:

Bring the activity to a close by posing the following questions, as well as allowing the participants to formulate more questions about the topics. (Investigation of many of the questions is possible with the Groundwater Models Activity in the curriculum.) Discussion: How does septic wastewater get into the ground? Where does it go after the tank? How does water in the ground look near the well? Does it look like a pool or a river? Could your own septic system pollute your drinking water? What activities on top of the ground contribute to pollution? Does pollution get into groundwater?

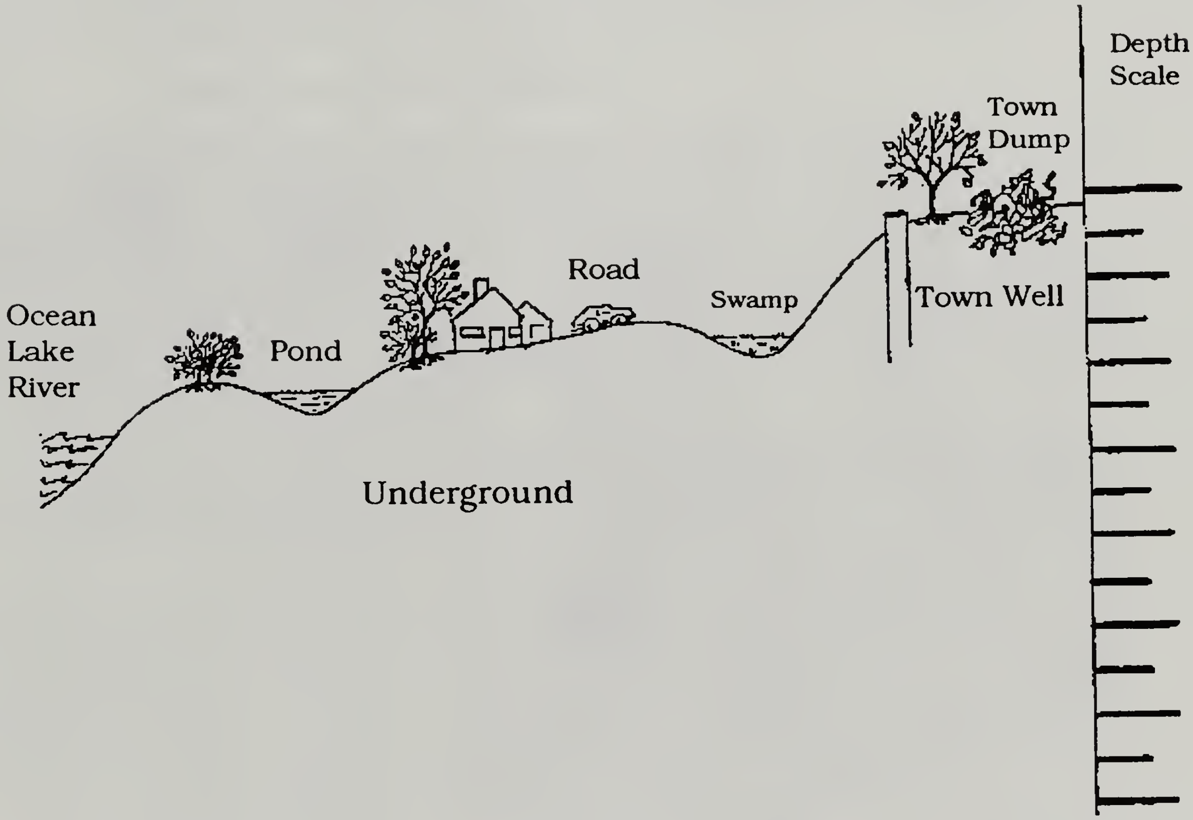
Extensions:

1. Groundwater Models Activity further illustrates groundwater dynamics.

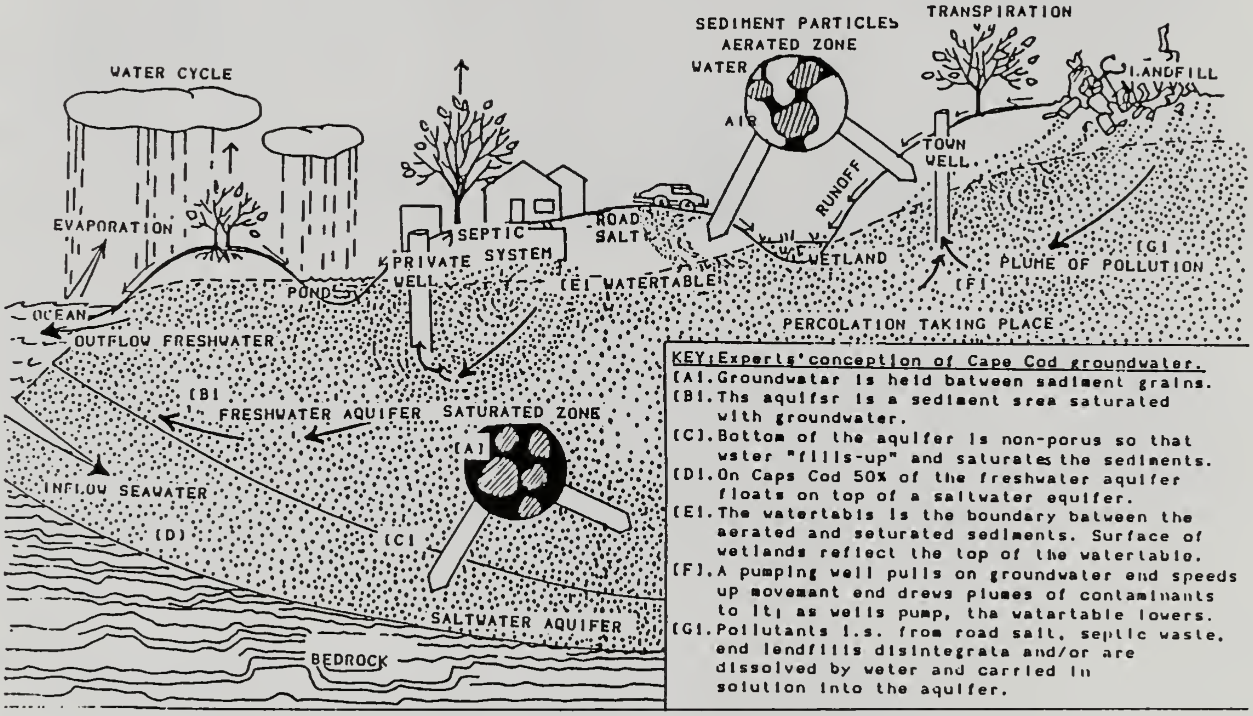
2. Permeability and Porosity of Different Soil Types Activity demonstrates how water moves through different soil types in the ground.

3. A trip to a wastewater treatment plant may provide information about how much water from the community enters the plant and where it goes after traveling through the facility.

4. Research the geology of your watershed area to determine how the aquifer and water tables were formed.


Depth Scale
Town Dump
Road
Swamp
Town Well
Ocean
Lake
River
Pond
Underground

THE "EXPERT" CONCEPTION OF GROUNDWATER



KEY: Experts' conception of Cape Cod groundwater.

(A). Groundwater is held between sediment grains.

(B). The aquifer is a sediment area saturated with groundwater.

(C). Bottom of the aquifer is non-porus so that water "fills-up" and saturates the sediments.

(D). On Cape Cod 50% of the freshwater aquifer floats on top of a saltwater aquifer.

(E). The watertable is the boundary between the aerated and saturated sediments. Surface of wetlands reflect the top of the watertable.

(F). A pumping well pulls on groundwater and speeds up movement and draws plumes of contaminants to it; as wells pump, the watertable lowers.

(G). Pollutants i.e. from road salt, septic waste, and landfills disintegrate and/or are dissolved by water and carried in solution into the aquifer.

Activity: Groundwater Models

Ages: 10 - 100

Goal:

Through observation and operation of the models, these hands-on activities help learners to understand groundwater and groundwater flow. Participants will learn how land use throughout a watershed impacts groundwater quality and coastal resources.

Note:

This entire sequence takes about 1 1/2 hours. Approximate durations for each part are listed. Allow time for clean-up and changing materials during the sequence. The Groundwater Models activities should take place in an environment where participants can sit and concentrate, and where the materials are most easily attained. The sequence is designed for small groups to work together in mutual discovery. The suggested order of the activity sequence and the concepts within each step are not the only way to teach groundwater dynamics. The teacher is encouraged to use any part of this activity sequence in any order. Finally, this activity sequence may be modified for slower or younger learners. These hands-on experiences appeal to learners of all levels.

Part I Aeration and Saturation

Summary:

1. Participants operate the model to observe aeration and saturation.

2. The group learns the meanings of the terms aeration and saturation.

3. The group applies the concepts they observe in the model to groundwater dynamics.

Time, Place and Materials

This part of the activity takes about 10 minutes and requires the following materials for each small group:

***sponge**
***container of water large enough so the sponge can lie flat**
***measuring cup**

Background Information: Primer for Educators, Geology and the Watershed p. II - 1.

Introduction and Motivation:

Hold up a sponge and ask what is inside of it. (Answers may include sponge material, and air - suggest air if the word does not come up)

ActivityProcedure:

1. Choose someone from each group to sink the sponge in the water and press down hard on top of it. Discussion: What has happened to the sponge? What does the sponge have in it now? Where did the air go? (Someone may mention seeing bubbles rise to the surface when they pressed on the sponge.)

2. Hold the dripping sponge above the basin. Discussion: Can anyone use one word to describe the state of the sponge now? (Answers may include soaked, wet, dripping - see if someone comes up with "saturated." If not, suggest it.)

3. Squeeze the sponge into a measuring cup. Each group will report how much water is in the cup. Discussion: Where was the water before it was squeezed into the cup? (In the spaces within the sponge.) What now occupies the spaces where the water was in the sponge? (Air.) Can anyone use one word to describe the sponge now? (Answers may include airy, empty, etc. You may ask what the opposite of "saturated" is to help them. If they don't know, introduce the word "aerated" and ask if anyone is familiar with that term.)

Closure:

Ask the group to define the terms saturated and aerated. Write them down. The group may come up with some metaphors for the sponge activity - the sponge as ground that sometimes contains air, sometimes water. Place another sponge above the wet sponge; which one represents the aquifer or water table? Which one is saturated, aerated? If the sponges are in the container, what represents the bottom of the aquifer?

Part II Permeability, Porosity and Percolation

Summary:

1. Participants operate the model, observing permeability and porosity of sand and the percolation of water through sand.

2. The group masters the terms permeability, porosity and percolation.

Time, Place and Materials
This activity takes 15 minutes and require the following materials for each small group:

*vials full of beach sand. The vials are about 2" high and 0.5" in diameter. Use sand of the same grain size. It should be easy to insert the pipettes into the sand.
*pipettes or eyedroppers
*container of water
Background Information: Primer for Educators, The Waquoit Bay Watershed, p. II - 2

Introduction and Motivation:

Ask the participants what is inside of the vial of sand (air and sand.) Discussion: If this were the ground, how would you describe it? (Aerated). Ask each group to estimate how many pipettes full of water it will take to fill up the vial. List the estimates.

Activity Procedure:

1. Demonstrate pipette use. (Squeeze the pipette first, then insert it into the container of water; release the bulb and watch it fill up.) Squeeze water into the vial of sand. Let small groups practice filling up the pipette and drizzling the water down the inside wall of the vial so they can see the water entering the sand. Discussion: What is happening to the water? What is it doing? (Give participants time to think of analogies, e.g., it looks like it's flowing through a maze, it moves like a worm, etc.) There is a word that describes the action of water passing through a substance. Does anyone know what it is? (Coffee maker is a good hint. Percolation is the answer.) Sand is a porous substance. What does that mean? (It is full of holes or has spaces between the grains and can hold water within those spaces.) Some substances have greater porosity than others and are thus able to hold more water, relative to their mass. Therefore, porosity refers to the amount of water a substance can hold.

2. The groups fill up the vials until the water forms a small "pond" over the sand. Discussion: Sand is permeable - what does that mean? (The sand allows the water to flow into and throughout its spaces.) Some soil types, such as clay or bedrock, are less permeable than others, allowing less water to flow through it in a given amount of time. Therefore, permeability refers to the rate at which water passes through a substance. What is happening inside the vial? (Water is filling in the spaces where the air used to be - saturation.) How did the pond form at the top? (The pond is on top of saturated ground.)

3. Squeezing the bulb of the pipette first, the participants slide it down the side of the vial, fairly deep, but not to the bottom, and then release the bulb. Discussion: What did the pipette draw into it? Why isn't there much, if any, sand in the pipette? (Liquids flow more easily than solids.) What happened to the pond? How does this correlate to human uses of water and the effects on the availability of water? (Overuse of this resource leads to depletion of the aquifer and lowering of the water table.)

4. Have the participants "recharge" the aquifer by squeezing the water in the pipette back into the vial. How does recharge of groundwater occur in natural systems? (When it rains, or when water goes back into the ground, e.g., effluent from homes.)

Closure:

The group can mimic a drought using their pipettes and sand vials to remove all the water, leaving only damp sand. This prepares the vial for the next part of the activity sequence. Discussion: What causes a drought? (Insufficient precipitation or recharge and evaporation depletes the water in the ground.) What does the pipette represent - what brings water into some of our homes? (Wells)

Extensions:

At this point participants may think they have changed some of their ideas about water under the ground and should be encouraged to make changes on the Groundwater Cross-Section diagram.

Part III Plumes

Summary:

1. By operating the model participants will observe a pollution plume in groundwater.

2. The effects of a pollution plume on groundwater are illustrated.

Time, Place and Materials

This activity takes about 15 minutes and requires the following materials for each small group:

***the sand vials used in Part II**
***pipettes**
***water**
***sugar-free grape Kool-Aide crystals (represents pollution)**

Background Information: Primer for Educators, "Groundwater Pollution and Demography", p. II - 9.

Introduction and Motivation:

Ask participants to list some substances that are put on or into the ground near their homes. Discussion: Participants might mention salt and sand on the roads in winter, fertilizer on lawns, golf courses and farms, oil and gases on roads and driveways, etc. What will happen to these materials when it rains? (Some will run off impervious services and go into the ground, and then into rivers, lakes and bays. All will contribute to the water in the ground.)

Activity Procedure:

1. Place 1/4 teaspoon of "pollution" (Kool-Aid crystals) on the top of each sand vial near the edge where it is visible. "Rain" on the ground by drizzling the water over the "pollution." Continue to drizzle the water until a small pond forms. Discussion: What happens to the pollutant? What happens as the rain continues? Is the pollutant spreading?

2. After the pond forms, ask participants to pump out the water and observe the movement of the plume. Discussion: What is happening to the pollutant now? This is what is called a plume; can anyone explain what a plume is? Will the plume ever reach the pipette? (If the colored water doesn't enter the pipette instruct the participants to "rain" again and draw up the water again. Eventually the plume will travel all the way to the pipette.)

Closure:

Ask if the group has seen this happen anywhere before (Drinking from a straw is similar.) Ask them to explain how their observations apply to a town well and surface pollution. What could happen if a leaching field is too close to a well source?

Clean Up:

Put the colored sand into a jar and flush with clean water. Spread it out to dry and use again.

Extensions:

Where does the water go once it enters the ground?

Part IV Water Tables and Aquifers

Summary:

1 By operating the model, participants observe a water table and the workings of a simple well driven into a porous, sandy aquifer.

2. This second modeling experience expands the knowledge gained from the previous experience with the sand vials. Participants should make changes to the Groundwater Cross-Section diagram, as they apply.

Time, Place and Materials

This part of the activity sequence takes about 20 minutes and requires the following materials for each small group:

*3"x3"x5" plastic container filled with coarse, washed gravel. In one corner a plastic tube (that does not quite touch the bottom) is secured in place. The tube represents a well.
*turkey baster
*container of water
*food coloring

Background Information: Primer for Educators, Geology and the Watershed p. II - 1.

Introduction and Motivation:

Place a few drops of blue food coloring in each container of water. The dye makes it easier to see the movement of the water through the gravel.

Activity Procedure:

1. Create a depression in the gravel along one side of the container. Discussion: What does the model contain right now? (Gravel and air.)

2. Add water to the container (not to the tube) with the turkey baster until the depression begins to fill up. Discussion: Ask the class to describe permeability, porosity, percolation and saturation as they observe these processes. What does the depression filled with water represent? (a pond) Participants may name some nearby ponds. Why does a pond forms in one place and not another? (Ponds occur where the land drops below the water table.) Participants should identify the aquifer and the water table in the model.

3. What happened to the tube on the side? Ask class to predict what will happen if they remove water from the tube. Instruct them to remove some water from the tube with the turkey baster. Discussion: Did the tube fill with water even though no water was put directly into it? What effects does removing water have on the nearby pond ? What do the tube and turkey baster represent? (a well) How can you "recharge" your well? (Rain on the model.)

Closure:

Participants should translate their new understandings to the Groundwater Cross-Section diagram. The group should discuss the new information, generate new questions and come to a more accurate understanding of groundwater dynamics.

Extensions

Where is the bottom of the aquifer or water table in our watershed? How is the bottom represented in the models? How deep does the water go in the ground in this area?

Part V Defining the Bottom of the Aquifer

Summary:

1. The class discusses the geology of the watershed under study and learns how to determine the bottom of the aquifer.

2. Participants observe freshwater floating above saltwater.

Time, Place and Materials

The instructor may operate the model for the entire group, or small groups may do it on their own. The model requires the following materials:

*test tube
*pipette or eyedropper
*saltwater, blue food coloring (made with regular tap water and table salt - mix salt in until the solution is saturated)
*freshwater, yellow food coloring

Background Information: Primer for Educators, The Waquoit Bay Watershed, p. II - 3.

Introduction and Motivation:

Ask what happens if saltwater and freshwater are combined in a test tube. The groups can draw an extension of the Groundwater Cross-Section diagram, showing how they think salt and freshwater mixing occurs at the sea's edge.

Activity Procedure:

1. Using the pipette, fill the test tube 1/3 of the way with saltwater. If you use one test tube for the entire group, each participant may help fill the tube.

2. Put your hand around the tube,so students can not see the inside (create an air of suspense); tilt the tube to one side and ask participants to slowly drizzle the freshwater down the inside wall of the tube. Fill the tube 2/3 full.

3. Show the test tube to everyone. Let the group interpret what they see. (The freshwater should float on top of the saltwater. If it doesn't, increase the amount of salt in your saltwater solution, or add the freshwater more slowly and carefully to discourage any mixing between the fresh and salt water. Practice before doing with the group!)

4. Ask participants to predict what will happen if you invert the tube. Place your thumb over the opening and slowly invert the tube. (The freshwater should still float above the saltwater. A green area between the yellow and blue, indicates that some mixing has occurred. If the inversion is done too quickly, the entire solution will turn green. Again, practice makes perfect!.)

Closure:

Ask participants what will happen if you shake the solution. Shake it and leave it overnight. Will the solutions separate? (Check it in the morning.)

Extensions:

This activity may generate questions that can be used as research opportunities later.

Activity: Permeability & Porosity of Soil Types

Ages: 10 - 100

Goal:

To understand how the permeability and porosity of different soil types contributes to movement of groundwater.

Summary:

1. A model is used to explain permeability and porosity of different soil types.

3. The effect of different soil types on the flow of groundwater is discussed.

Time, Place and Materials

This activity takes 30 to 45 minutes. Prepare materials a few days before the activity.

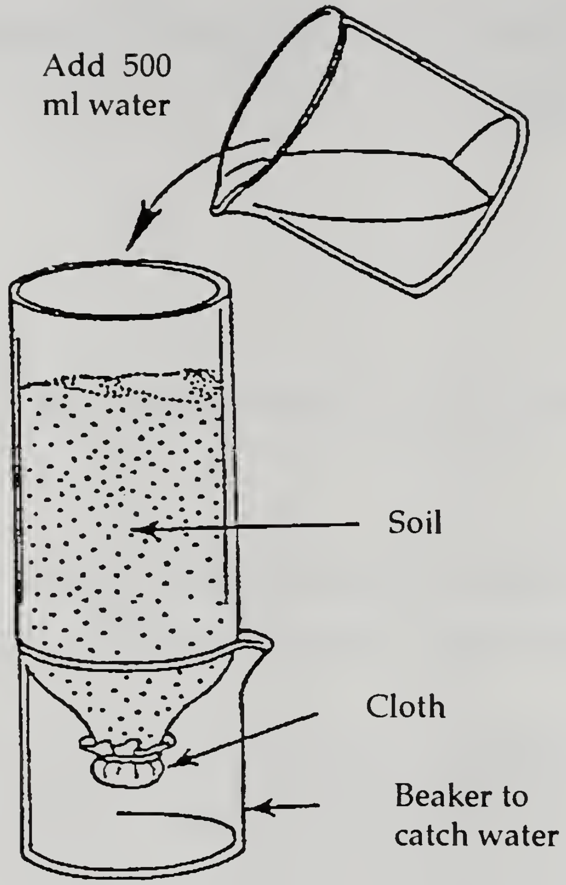
Soil Preparation:
*"rich" soil - contains organic matter, black or dark brown in color, crumbles easily; break up any clods.
*"poor" soil - lacking in organic matter, light in color, hard and cloudy, or use beach sand if this is a feature in watershed.
*two paper shopping bags; label one" rich soil" and one "poor soil."

Spread the soil out to dry a few days before the activity, or put the soil on cookie sheets in the oven at 200 degrees F for 30 minutes. Break up any clods before drying. After the soil is dry, transfer to the appropriate paper bag.

Other Materials:
*two soda bottles - one marked rich and one marked poor
*sharp knife or scissors to cut the bottoms off the bottles
*two squares of cloth
*two rubber bands

Cut the bottoms off the soda bottles. Place a square of cloth over the mouth of each bottle and secure it with a rubber band.

*4 beakers, 500 ml each, two labeled rich soil and two labeled poor soil
*a 500ml graduated cylinder
*watch or clock with a second hand
*Water Absorption Data Sheets
Background Information: Primer for Educators, "Geologic and the Watershed", p. II - 1.



Introduction and Motivation:

Ask participants to define permeability and porosity. Record their answers and see if they change their minds at the end of the activity. Discussion: How are these terms different? (Permeability is the rate at which water passes through a solid medium. Porosity is the amount of water the solid medium can hold.) How can we determine the permeability and porosity of different types of soil? (Let participants describe some ways to find out.)

Activity Procedure:

1. Introduce the activity. Fill the bottles 3/4 full with the soils (make sure both bottles contain the same amount of soil). Stand each bottle in the appropriately labeled beaker. Discussion: What is the difference between rich soil and poor soil? (Rich soil has organic matter; poor soil has no organic matter).

2. Have participants predict what will happen when the two soils are tested. Discussion: Which one will let water pass through it the fastest? Which one will hold the most water? Record the predictions.

3. Fill the beakers with 500 ml of water. Pass out the recording sheet and assign someone as timekeeper. Explain that they will record the time (a) when the water is first poured into the soil; (b) when they see the water begin to drip out the other end, and (c) when the dripping stops. Discussion: How long will it take for the water to drip through the rich soil? the poor soil? How long until the dripping stops? Record these predictions.

4. Let the water flow! Add the water slowly so the soil surface is not disturbed. As the water sinks into the soil, add more, using water from the appropriately labeled beaker. Record observations on the Water Absorption Data sheet.

5. Twenty minutes after you began adding water to the soil, determine the amount of water not absorbed as follows:

(a) Pour any of the original 500 ml of water remaining in the rich soil beaker into the graduated cylinder. Then, carefully pour the water left standing on top of the rich soil into the same graduated cylinder. Avoid disturbing the soil as you poor the water off its surface. Now, determine the volume of water in the cylinder. Record this amount under the heading "Volume of Water Not Entering the Soil" in the "Unabsorbed Water Data" data sheet.

(b) Determine the volume of water that passed through the rich soil sample. This is the water that dripped into the lower beaker. Enter this amount in the "Unabsorbed Water Data" table.

(c) Calculate the amount of water that was not absorbed by the rich soil sample by adding the volume of water that did not enter the soil to the volume of water that passed through the soil. Enter this sum in the "Unabsorbed Water Data" table.

(d) Repeat steps a,b,and c for the poor soil sample.

6. Determine how much water the rich soil and the poor soil samples absorbed by subtracting the volume of unabsorbed water from 500 ml (the starting water volume) for each sample.

Closure:

What do the findings tell you about groundwater movement? What happens to groundwater at the sandy shoreline (or in poor soil located in other areas)? How is this different from groundwater movement in the forest or in the woods? Why do you think that the soil sample absorbed different amounts of water?

Extensions:

1. The Placing The Watershed in a Geographic Context Activity uses geologic information to define the bottom of the aquifer and to delineate the boundaries of the watershed area. Soil types in your area have much to do with these features of the watershed.

2. Demonstrate the filtering action of sand and soil by using "dirty" water in another test with the same set up as the Permeability And Porosity Activity. See what kinds of "dirty" water, sand and soil filter well and not so well.

3. Provide a list of soil and rock types in your area for the group to locate and retrieve for labeling.

4. Invite a geologist to speak to the group on different soil and rock types from your area.

This activity was taken, in part, from the activity How Much Water Can Different Soils Hold? in Earth: the Water Planet.

Water Absorption Data

	Rich Soil	Poor Soil
Time when water is added	________	________
Time when dripping begins	________	________
Time when dripping stops	________	________

How many minutes did it take for the water to begin dripping into the beaker from
(a) the rich soil? ___________ minutes
(b) the poor soil? ___________ minutes

Twenty minutes after you begin adding the water to the soil, determine the amount of water that was not absorbed as follows:

(a) Pour any of the original 500 ml of water that remains in the rich soil beaker into the graduated cylinder. Then, carefully pour the water left standing on top of the rich soil into the same graduated cylinder. Try to avoid disturbing the soil as your pour the water off its surface. Now, determine the volume of water in the cylinder. Record this volume of water under the heading "Volume of water not entering the soil" in the "Unabsorbed Water Data."

(b) Determine the volume of the water that passed through the rich soil sample. This is the water that dripped into the lower beaker. Enter this volume in the "Unabsorbed Water Data" table.

(c) Calculate the amount of water that was not absorbed by the rich soil sample by adding the volume of water that did not enter the soil to the volume of water that passed through the soil. Enter this sum in the "Unabsorbed Water Data" table.

(d) Repeat steps (a), (b), and (c) for the poor soil sample.

Unabsorbed Water Data

	Rich Soil	Poor Soil
Vol. of water that did not enter the soil	________	________
Vol. of water that did not enter the soil	________	________
Total unabsorbed water	________	________

Determine how much water the rich soil and the poor soil samples absorbed by subtracting the volume of unabsorbed water from 500 ml (the starting water volume) for each sample.

Water absorbed by soil sample = 500 ml - Total unabsorbed water

Water absorbed by "poor" soil = 500 ml - _____ ml = _____ ml

Water absorbed by "rich" soil = 500 ml - _____ ml = _____ ml

Activity: Using Well Measurements To Picture The Water Table

Ages: 11 - 100

Goal:

To learn how geologists use well measurements to construct a picture of the water table and watershed boundaries.

Summary:

1. Participants draw and plot information on a graph andl learn how to develop a scale on the graph.

2. The class will plot a profile of the land surface.

3. Using well depth measurements, participants will calculate the elevation of the water table above sea level and plot a profile of the water table below the surface of the land.

4. Participants will suggest how these measurements could be used to delineate the boundaries of a watershed area particularly one that is not governed by the topography of the land.

Time, Place and Materials

This activity takes about 25 minutes to complete in an environment conducive to writing. The following materials are required for each small group:

***graph paper**
***the "Data Sheet for Water Table Calculation"**

Background Information: Primer for Educators, "Geology and the Watershed", p. II - 1.

Introduction and Motivation:

Participants think of ways to determine the elevation of the water table above sea level. Discussion: How could we find out how deep the water table is beneath the surface of the ground? (dig) We already have holes dug to the water table; for what purpose? (Wells for drinking water and other uses.) How deep do these well go? When does the digging stop? (Some may answer in numbers of feet, be sure they say "until it reaches water.") Does a well reach only to the top of a water table? (No, the well needs a constant supply of water. Wells are dug down many feet below the water table to ensure a constant source.) Why isn't there a constant source right at the top of the water table? (Each time the well draws up water, it lowers the level of the water table. Then it is recharged from surrounding groundwater, filling up again to maintain a fairly stable water table level.) What if it didn't rain for a long time, but the well was continually used? (The water table would drop, and recharge might not bring it up to the same level every time.) Wells can tell us a lot about the state of groundwater, and whether there is enough to go around. Wells can also show us water table levels beneath the ground.

Activity Procedure:

1. Pass out the data sheets (an original is provided at the end of this activity), one per small group. Discussion: Which well site on the data sheet is at the lowest level above sea level? (Point 1) Which well site has the water table closest to the surface of the land? (Point 1) Which well site is the highest above sea level? (Point 3) Which well site has the water table farthest from the surface of the ground? (Point 3) Does this initial observation suggest anything about the water table? (Some may think that the water table is staying at the same level all the time.)

2. Now determine the elevation of the water table above sea level. Discussion: How can you figure out the elevation of the water table above sea level? (Subtract the depth of water in the well from the elevation of land above sea level.) Does the water table stay at a constant level? Why not? (It is possible that recharge isn't the same at every well point. Other features under the ground can affect the water table level at a given point.)

3. Pass out the graph paper and instruct the group to use the information on the data sheet to draw a profile of the land and the water table beneath it. Represent sea level on the graph, too. Discussion: How can you plot these measurements on the graph? First determine scale. (Looking at the data, participants could use a scale in increments of 25, 50 or 100 feet, depending on space. ªProvide a scale for a younger group.) What information should go on the x axis? the y axis? (To get a profile of the land with the water table under the land, place feet above sea level on the y or vertical axis and the well point numbers on the x or horizontal axis. Refer to Figure 4 in Primer for Educator.)

4. Plot the elevation of land above sea level first. Discussion: What direction does water flow over the surface in this picture? (From point 3 to points 2 or 4.) From what we have just said, what do we already know about water? (That it doesn't flow uphill.) Does water flow the same way underground? (In most cases, yes.)

5. Plot the elevation of the water table above sea level. Discussion: Is there a pattern emerging? Which well point is the highest? (point 4) The lowest? (point 1) So, does the surface of the land show us where the water table is? (Not necessarily - it can reveal ponds when the land drops below the level of the water table.)

Closure:

In what direction is the water flowing underground in this picture? (From point 4 downhill to points 3 and 5.) What could point 4 represent to a geologist? (A boundary marking separating two watersheds.) What could explain the changes in water table levels below the land? (Different recharge rates at different point, underground features that disrupt the flow of water, e.g., random glacial deposits of bedrock, clay pans, etc.)

Extensions:

1. Permeability And Porosity Of Sediment Types activity to expand understanding of how different aquifer mediums will hold water.

2. This project could become an extensive mapping project, creating a "topo map" of the water table under the surface of the ground.

3. Invite a geologist to speak about your watershed.

Water Table Data

Point Number	Elevation of Land Above Sea Level (feet)	Depth to Water in the Well (feet)	Elevation of Water Table above Sea Level
1	800	23	
2	1150	225	
3	1250	275	
4	1100	50	
5	1100	75	
6	1000	50	

Looking At Our Watershed

Activity: Placing the Watershed in a Geographic Context

Ages: 10 - 100

Goal:

To understand the concept of a "watershed" and distinguish its boundaries.

Summary:

1. Using Geographic Information System (GIS) maps and topographical (topo) maps, participants will locate the land area in question.

2. Geological features that are key components of the watershed and its boundaries will be pointed out and discussed.

3. Participants will identify the types of weather and substrate common to the area that may affect watershed dynamics.

4. Participants will define, explain or generate questions about the boundaries of the watershed.

Time, Place and Materials

This activity takes about 15 minutes and needs to be in a place conducive to looking at large maps. Materials include:

*map of the world
*map of the continent
*map of the United States
*GIS and topo maps that show the entire watershed area you are studying
*any other specific maps that further illustrate features of particular importance to your watershed
*copies of maps that participants may use to draw their ideas of where watershed boundaries lie

Background Information: Primer for Educators, "The Waquoit Bay Watershed", p. II - 2.

Introduction and Motivation:

Have the group examine all the maps and locate their area on them. Discuss larger watershed areas, i.e., the Rocky Mountain continental divide.

Activity Procedure:

1. Ask participants to locate the two largest watershed areas in the country - east and west of the Rockies. Discussion: What land features determine the boundaries of these two watershed areas? What will be the general directions of flow for the two watersheds? (Pacific and Atlantic oceans.)

2. Using the GIS and topo maps of the local area, discuss which geological features determine the boundaries and direction of flow. Discussion: Do any of the surface land features in this area govern where the boundaries of the watershed may lie? Which general direction will the water flow? Note: The direction of flow and boundaries of your watershed may not be governed by surface land features, such as on Cape Cod or Long Island. Let the participants try to determine where the watershed boundaries lie. Ask participants to explain how these boundaries were delineated. (Boundaries of the Waquoit Bay watershed were delineated in the Using Well Measurements To Picture The Water Table activity.)

3. Participants list some of the land use types and natural features found within the watershed area and explain the ecology. Discussion: What does the topography of the land look like? (flat, hilly, mountainous) Are there expanses of forest, farmland, water areas? What kinds of weather does the area have - severe or mild climactic changes? (Include storms specific to your area - nor'easter, hurricane, tornado, etc.) How about substrate - what lies under the surface of the ground? (Sandy soil, bedrock, gravel, random boulders, other geological features.) What do all of these factors have to do with the watershed dynamics of the area? (Substrate may decrease or increase the flow of groundwater, or may cause stagnation in places. If water flows too quickly and directly to a catch basin, such as in the Waquoit Bay watershed, the water won't filter very well and will contribute high levels of nutrients and pollution to the Bay.)

Closure:

Participants may take a quick "Raindrop Journey" down the watershed describing where the rainwater may go. Discussion: Point to different areas on the map and ask where the water goes. Water anywhere within the watershed will eventually flow to the same area.

Extensions:

1. Using Well Measurements To Picture The Water Table Activity, to see which direction the water flows in your watershed.

2. Land Use Survey activity brings participants out to the watershed.

3. Have participants draw their own maps from those used in the Placing the Watershed in a Geographic Context activity to use as recording sheets for the Land Use Survey.

Activity: Land Use Survey

Ages 10 -100

Goal:

Participants look at patterns of human land use and examine the various impacts these land uses may have on the watershed.

Summary:

1. Participants journey through the watershed recording their observations of land use patterns.

2. Participants describe possible impacts each type of land use may have on the watershed.

Time, Place and Materials

This activity takes about 20 minutes. Travel no more than 10 miles and go slowly so participants can make accurate recordings of the land use patterns in the area. Materials include:

*clipboards
*pens and pencils
*road map of the area
*copies of the Land Use Survey sheet, one per person

Optional: If a ride through the watershed is not possible, a slide show or GIS map of the area may be substituted.
Background Information: Primer for Educators, "Eutrophication", p. II - 5.

Introduction and Motivation:

Using a road map of the route ask participants to predict what land use patterns they will encounter.

Activity Procedure:

1. Establish the roles of the participants. Choose drivers, recorders, mileage keepers, and people to identify different land uses along the way.

2. Record human land uses and naturally occurring land patterns (forests, ponds, etc.) on the Land Use Survey form. Discussion: How do houses affect the surface and groundwater? How does industry affect water in the system? Why are developments located at particular spots? How may developments affect the watershed? Where do we find natural landscapes dominating and why in those spots?

Closure:

Participants summarize their findings. Discussion: What are the overall patterns we have observed? As a result of the land uses, what kinds of impacts on the watershed should we expect? How do these impacts affect the water we drink and the water used by other plants and animals?

Extensions:

1. Use the records from this activity in the Watershed Model Construction Activity.

2. Do the Land Use Planning Activity to practice planning towns with minimum negative impacts on the watershed system.

3. Plot the observed land uses on a road map or a map created by participants.

Land Use Survey

Identify residential developments (note differences intheir densities), commercial development, recreational uses, agricultural uses, industrial uses, monitoring wells, etc.

Distance from Waquoit Bay

0 miles

3 miles

5 miles

7 miles

Notes and comments:

Activity: Watershed Model Construction

Ages 10 - 100

Goal:

Participants apply the concepts learned in Watershed Model Construction to an actual watershed.

Summary:

1. Participants build a model of a watershed from the ground up.

2. Through peer interaction, they decide how to plan the land use patterns by creating their own plan or copying a plan they have seen.

3. Participants witness watershed dynamics by operating the model.

4. The learners discuss how land uses impact watershed dynamics.

Time, Place and Materials

This activity takes about 30 minutes. The site is the beach or at a sand table. Materials include:

*a large watering can with a sprinkle nozzle

*small model houses, people, farm animals, cars, airplanes, tractors, factories, pieces of slate to represent parking lots and any other features unique to the watershed you wish to represent.

*large sheet of plastic to simulate the water table or an impervious layer such as a clay pan or bedrock

*small sponges (about 0.5" squared) dyed different colors using food coloring. (Store each color in a separate plastic bag; 15 pieces of sponge of each color.)

Optional: Use records from the Land Use Survey Activity to plan the land use patterns for the Watershed Model Construction. Or, use a map showing the watershed you wish to represent in the model to assist in the planning stages of this activity.

Background Information: Primer for Educators, "Groundwater Pollution and Demography" p. II - 9.

Introduction and Motivation:

Discuss the terms watershed, groundwater and surface water. Assign a notekeeper or have each person record their ideas about the terms. At the end of the Activity the students can compare their new understanding to their prior ideas.

Activity Procedure:

1. Ask people to take notes during the activity, or assign a notekeeper. This record will be invaluable in reviewing how ideas change as a result of the activity. Discussion: We will create our own watershed model to observe the dynamics of this system at work. What are dynamics? (changes and

interactions within a system.)

2. Participants build a mound of sand approximately 3 feet wide, 5 feet long and less than 1 foot high, sloping lengthwise. Discussion: This mound represents part of a watershed. How do you think water will move over the land ? (Gravity.)

3. Place the sheet of plastic over the mound and cover it with another four to six inches of sand. Discussion: The plastic layer represents the water table. What is a water table? (top of the aquifer.) Does the level ever change? (yes) How or why? (precipitation, human uses, recharge, etc.) How can we tell where the water table is at a given place and time? (Look at the surface of a pond or underground well measurements.) Does the water table ever show above ground? (yes) When and Where? (ponds, lakes and rivers.)

* Optional: The plastic layer may represent an impervious layer such as bedrock or a clay pan. To represent the type of watershed you desire, the depth of the sand on top of the plastic may be thicker or thinner than 4-6 inches. The discussion may then include questions and comments about a system that includes these features in the watershed.

4. Construct the water bodies in your watershed showing that land that drops below the water table fills in with water creating a lake or river. To simulate a body of water, remove the sand to reveal the water table (plastic). Discussion: A watershed consists of a land area with different water bodies that flow in a common direction. Water may be above the ground as a lake or river, or may flow underground. How are water bodies formed above the ground so that they are visible to us? Why do they occur where they do? (The surface of the land has dropped below the water table. Sometimes they occur in places where glaciers have created a hole, or where the topography changes for some reason.)

5. The group decides which human land use features to represent in the model, i.e., farms, neighborhood developments, airports, roads, waterways, etc. These may come from the Land Use Survey Activity. Smaller groups may plan specific features and decide where to site them in the watershed. The small groups then choose model pieces. Discussion: Where do we see most residential developments? (usually near open waters) How about industry or farms? Where will roads be built? Where is the airport?

6. Building begins. Discussion: What kinds of impacts do these features have on the water that flows through this area? (Ideas may include septic effluent from houses, runoff from fertilized fields of farms or golf courses, runoff from roads and large paved areas like parking lots or runways and effluent from industrial plants. Someone may suggest acid rain as a nutrient contributor. The changes on the surface of the land may alter the flow of water across it.) Categorize the kinds of impacts mentioned and represent each of these with one color of sponge.

7. Have the participants place the appropriate color sponge next to the buildings or features of the watershed where that impact is most likely to occur (be sure to place some sponges right on top of impervious surfaces such as the slate "parking lot" or any other hard surfaces you have chosen to use; this demonstrates runoff quite nicely). Use plenty of sponges to give a dramatic effect. Discussion: Let the participants predict what will happen next. Tell the participants that it's going to rain on the watershed. What do they think will happen to the dye in the sponges? Where will it go? How far? How deep? Will impacts occurring at the top of the watershed affect the bottom of the watershed?

8. Now it's time to rain. Someone who doesn't mind holding up the heavy watering can for a while is a good designated rainmaker. Participants may want to improve waterways to ensure the smooth running of the water through the model-size rivers and ponds. Discussion: erosion may occur in the watershed. Why doesn't the sand stay in place? (no plants to hold it in place) Why are the ponds and rivers filling up and running? (The ground reaches its saturation point and the water begins to flow across the surface.) Where is the water table level when the pond is full?

9. After the rainstorm is over, participants describe their observations. Discussion: Where did the different dyes go? Did the events occurring at the top of the watershed affect the bottom? If not, would the effects ever reach all the way down? (probably) How deep did the dyes percolate into the sand? (Have students dig into the sand to observe a cross-section.) At what point did the water stop going down into the sand? Is all the sand above the water table saturated? Did the dyes flow as deeply as the water?

Closure:

Read over the record from the beginning of the activity to review preconceptions and discuss how ideas have changed. Apply the dynamics of the model to real life watershed dynamics. Discussion: In a real town, how are some of these impacts controlled? (Septic tank regulations, caps on the amount of pavement allowed within an area, monitoring of fertilizers on farms and golf courses, catch basins on roadsides.)

Clean-up: Pick up all sponges, model size pieces and retrieve the plastic bag from under the sand. Spread out the sand pile, making sure no large mounds or ditches are left for others to trip on, and spread out all the food-colored sand as well. People who come along after you will have no idea what all the "pollution" is.

Extensions:

1. Land Use Planning Activity lets students plan a town that would have minimal impacts on the watershed.

2. Water Quality Sampling Activity demonstrates the effects of human land uses on water quality.

3. A trip to a wastewater treatment plant shows how we treat wastewater and possible side effects of treatment.

4. Invite town officials to come and speak to the group on some of the issues involving watershed protection and management.

5. Research alternative methods of controlling the impacts discussed in the activity (Denitrifying septic tanks, runoff controls, fertilizer-free golf courses, etc.)

6. Translate the Watershed Model Construction experience into a large art project such as a mural depicting how human and uses impact the watershed system.

Activity: Land Use Planning

Ages 10 - 100

Goals:

Participants learn that no land use plan is foolproof; any changes made to the land affect the watershed. We can only try to plan carefully and encourage informed decisions.

Summary:

1. Participants create a land use scheme with minimum impacts on the watershed.

2. The group discusses and evaluates lifestyle changes that may minimize damaging effects on the watershed and discover the difficulties of valuing things like clean air, clean water and open space.

Time, Place and Materials

This activity takes 30 minutes to an hour, depending on the length of discussions about developing their land use scheme. This activity may take place indoors or outdoors. It requires the following materials:

*one (or more) rough drawing of the watershed on a chalkboard, or an oak tag cut-out, with water bodies included
*colored construction paper
*scissors
*tape

Note: For a large group, provide several outlines of the watershed, so that small groups may plan all the way through for a watershed. Then the groups can compare their results.
Background Information: Primer for Educators, "Groundwater Pollution and Demography," p. II-9.

Introduction and Motivation:

Ask participants to list land uses in the watershed area.

Activity Procedure:

1. Participants form small interest groups, representing the different categories of land use they listed. Possible interest groups include:
    residents, farmers, business interests (e.g., gas station owners), park department personnel, highway department personnel, factory owners and workers, municipal services (e.g., landfill and wastewater treatment plant).

2. The interest groups list pros and cons of their land uses Discussion: Small groups may interact and give suggestions to one another. Encourage objectivity.

3. Each group chooses one color of construction paper and one shape to represent their land use type. Create a legend identifying which color/shape represents which type of land use. Cut out pieces representing the different types of use. Label each piece for direct reference on the drawing.

4. The small groups discuss where they want their site(s) in the watershed and which other land use types they prefer close-by or far away. Discussion: Exclusion of any land use type is unacceptable. Preserve wildlife habitat in the area. Everyone must agree on the final plan.

5. One person from each group tapes their shapes to the drawing. Permit changes only after everyone has had a turn. The group must try to create a land use pattern that has the least effect on the watershed. Discussion: This may turn into a town meeting of sorts, in which each group defends their land use and may takes offense to the building of an undesirable neighbor. Encourage constructive discussion and individual ideas. Ask how one might best represent their needs to convince the group of their land-use plan. Can they make a deal with neighbors, or promise certain practices that will ensure fair and careful use of the land?

6. Continue discussion, encouraging everyone to share their ideas. Point out the consequences of any land uses, but acknowledge the difficulties of choosing one use over another. Discussion: Explain what would happen if businesses and factories shut down. (It may destroy the economic base of the community.) What if farms were abandoned? (This could affect food supplies, and farms are preferred habitat for some wildlife.) What land uses might use water from the water supply? (All; ask the participants to describe how each land use type uses water.) What is the condition of the water that goes back into the local supply? (Septic effluent from homes, runoff from farms, industrial effluent, etc.) Describe the kinds of effluent that come from local businesses or industries. Emphasize that no solution is perfect, but we can minimize the effects of human land use on the watershed.

7. How does the water pass through the developed areas? Discussion: Who gets the water first in the watershed, next and last? What types of land uses are situated on rivers or other water bodies? What will the water carry as it travels further down the watershed? What is the final destination of all the water that flows through the watershed?

8. Participants discuss the overall effects the final plan may have on the watershed. Discussion: What will the water contain in the end? How will this affect the natural systems in this area? What about drinking water? Is there a danger that it will become contaminated?

Closure:

Discussion: What kinds of changes are you willing to make in your lifestyle to ensure a quality environment? What kind of value or price can we put on clean air, water and land? Are you willing to pay money for these things? How much of your paycheck would you give each week or month to pay for a clean environment?

Extensions:

1. The Water Quality Testing Activity demonstrates how human land uses impact the quality of water.
2. The Watershed Model Construction Activity demonstrates watershed dynamics at work.

3. Hold a mock town meeting, where participants can act out the procedures use to determine whether certain land uses are allowed in the town, and where they will occur.

4. Invite a town planner to talk about building within the watershed area and the political and environmental implications.

NOTE: Some of the ideas for this activity come from "Dragonfly Pond" in the Project Aquatic Wild curriculum.

Land Use Impacts on Water

Activity: Water Quality Testing

Ages 12 - 100

Goal:

By measuring critical components of the water column that are difficult to observe directly, participants will see that land uses have an impact on water quality.

Summary:

1. Participants measure dissolved oxygen (D.O.) and nitrogen in the water column.

2. Participants ask questions about water quality testing, and suggest reasons for measuring oxygen and nitrogen contents in water.

3. Participants record and interpret their findings.

Time, Place and Materials

This activity may take 30 minutes. It is best to perform the tests at the water body itself. If this is not possible, bring the sample to the group for testing. D.O. results will not be accurate unless the sample is properly collected in the test bottle and fixed before transporting. Materials required include:

*dissolved oxygen test kit
*nitrate or ammonium test kit
*jar for hazardous waste from nitrate or ammonium kit (wide mouth labeled, with cap)
*charts for recording D.O. and nitrate or ammonium data
*ongoing graph to plot D.O. results at a particular location

Background Information: Primer for Educators, "Testing for Dissolved Oxygen & Nitrogen," p. II - 9.

Introduction and Motivation:

Discussion: Why do we test for D.O. and nitrogen in the water? (D.O. levels indicate how well the waters are supporting aerobic life and high nitrogen levels indicate potential loading from land uses.)

Activity Procedure:

1. Ideally the group should travel to the water body to conduct the tests. The water body should have a history of nutrient loading and/or fish kill events. If traveling is not possible, retrieve test samples from the source. Remember that the D.O. sample must be fixed as soon as it is collected; the rest of the procedure can be completed later.

2. Perform the tests and keep records of the results. Follow the instructions in the kit. Encourage the entire group to participate. (One person may read the instructions while others do the steps.) Note: The instructions for sample collection provided with the kit may not be clear. Instructions for collecting the samples are given on the following page. Copy them and take them to the testing sight.

3. Discuss the groups' findings. Are there any patterns on the charts and graph? If not, how does the data compare to previous data? If there are no other data points, discuss expected ranges of D.O. (Healthy waters contain 5 to 10 ppm of oxygen. Values lower than 5 suggest hypoxia, while values greater than 10 indicate a productive oxygen source.)

Closure:

The "Fish Kill Mystery" scrambles the events that preceded the Great Waquoit Bay Fish Kill of 1988. Unscrambling the events is a fun activity and relates dissolved oxygen and nitrogen in the water column to fish kills.

Extensions:

1. Plotting Dissolved Oxygen Activity.

2. Algal Growth Experiment Activity demonstrates the response of algae to nutrient loading.

3. The Critiquing the Press Activity provides an opportunity to examine how a fish kill event was reported and to rewrite the article.

4. Compare and contrast D.O. and nitrogen data from several water bodies, rain water from puddles, faucet water, etc.

Sample Collection Instructions

Dissolved Oxygen Testing

The sample must be free of any air bubbles and must be fixed directly after the sample is collected to yield D.O. numbers that most accurately represent the amount of oxygen in the water column. Follow the instructions below.

1. Fill and empty the sample bottle 3 times with water from the water body to be tested.
2. Submerge the sample bottle at least 6 inches under water, with a thumb over the opening.
3 Hold the bottle upright under water and remove the thumb, allowing the bottle to fill to capacity.
4. Tap the side of the bottle to remove any air bubbles sticking to the inside.
5. Cap the bottle underwater.

The sample is now ready for testing. During the rest of the testing procedure, the bottle should sit on a flat stable surface. In the field, use a rock or even the top of the test kit. Any movement of the bottle may add oxygen to the sample

Nitrate Testing

Nitrate tests use cadmium as part of the process. This chemical can cause skin irritation and is considered hazardous. Instructors are advised to do this part of the test themselves. The completed test solution is considered hazardous waste and must be disposed of at a hazardous waste facility. Keep the remains of tests in a wide mouth jar and, bring it to Waquoit Bay National Estuarine Research Reserve or the Marine Biological Laboratory in Woods Hole for safe disposal.

1. When collecting, rinse the bottle 3 times with water from the water body to be tested. Perform the test.
2. After you pour the completed test solution into the hazardous waste jar, rinse out the test tubes with clean water. Pour this water in the hazardous waste jar also.

Dissolved Oxygen (ppm) Data Sheet

Name	Date	Time of day	Weather conditions	Dissolved Oxygen

Location ______________________

Nitrate/Ammonium Data Sheet

Name	Date	Time of day	Weather conditions	Nitrate or Ammonium

Location ____________________

Fish Kill Mystery

Reconstruct the events that led up to the Great Waquoit Bay Fish Kill of 1988. Number the events in the order you think they occurred to solve the Fish Kill Mystery.

_____ The algae photosynthesize and produce oxygen during sunny days.

_____ Depletion of the oxygen level in the water over the five day period creates an anoxic environment in Waquoit Bay

_____ At night, the algae, as well as other plants and animals, respire and use some of the oxygen produced during the day.

_____ Hundreds of fishes and crabs move into the shallows, trying to breathe where the air mixes with water most readily. Some are jumping out of the water gasping for air. Amphipods cling to boats or people to get out of the water to breathe.

_____ The weather turns humid and still with five cloudy days in a row.

_____ Nutrient loading of the Bay goes on for many years, from septic effluent, head dumping and acid rain.

_____ Oxygen production during the cloudy days is not enough to meet the needs of all the algae, other plants and animals.

_____ *Cladophora* and *Gracilaria*, two types of fast growing algae in the bay exposed to the nutrients, undergo massive blooms that choke out eelgrass beds and other plant life in the water.

_____ On the fourth morning dead winter flounder and other fish wash up on shore.

_____ At last the sun comes out and the plants begin to photosynthesize and produce oxygen again.

_____ A few hours later, more dead finfish, crabs and eels wash up on shore.

Fish Kill Mystery Answer Sheet

Reconstruct the events that led up to the Great Waquoit Bay Fish Kill of 1988. Number the events in the order you think they occurred to solve the Fish Kill Mystery.

___3__ The algae photosynthesize and produce oxygen during sunny days.

___7__ Depletion of the oxygen level in the water over the five day period creates an anoxic environment in Waquoit Bay

___4__ At night, the algae, as well as other plants and animals, respire and use some of the oxygen produced during the day.

___8__ Hundreds of fishes and crabs move into the shallows, trying to breathe where the air mixes with water most readily. Some are jumping out of the water gasping for air. Amphipods cling to boats or people to get out of the water to breathe.

___5__ The weather turns humid and still with five cloudy days in a row.

___1__ Nutrient loading of the Bay goes on for many years, from septic effluent, head dumping and acid rain.

___6__ Oxygen production during the cloudy days is not enough to meet the needs of all the algae, other plants and animals.

___2__ Cladophora and Gracilaria, two types of fast growing algae in the bay exposed to the nutrients, undergo massive blooms that choke out eelgrass beds and other plant life in the water.

___9__ On the fourth morning dead winter flounder and other fish wash up on shore.

___11_ At last the sun comes out and the plants begin to photosynthesize and produce oxygen again.

__10__ A few hours later, more dead finfish, crabs and eels wash up on shore.

Activity: Algal Growth Experiment

Ages: 10 - 100

Goal:

Participating in an ongoing experiment encourages an appreciation of the role of research in land use planning.

Summary:

1. Using the scientific method, participants will focus on a particular problem, the effects of nutrient enrichment on aquatic vegetation.

2 The group will experience the difficulties of studying an apparently straight-forward problem.

Time, Place and Materials

Note: The procedure assumes the experiment has been set up by the instructor. If one group of students will continue observations over a period of time, involve them in the set-up and daily maintenance . Materials include:

*a bucket with extra algae for students to hold and observe
*balance, accurate to at least 2 grams
*pan or tray to hold algae on the balance
*salad spinner
*graph to record daily data

Background Information: Primer for Educators, "Algal Physiology", p. II - 7.

Introduction and Motivation:

Have each participant take a handful of algae from the bucket. Ask how plants grow in water with no roots or soil. How do they get nutrients? (The nutrients are dissolved in the water.) How do plants "eat?" (They make their own food through the process of photosynthesis.)

Activity Procedure:

Note: The first two steps of the scientific method, 1. hypothesis, and 2. experimentation, were determined prior to the set-up of the experiment. The participants are asked to do the last three steps of the scientific method, 3. record observations, 4. record results, and 5. draw conclusions.

1. Discuss plant functions and explain the experiment. Discussion: What happens to the algae during the day and during the night? (Plants photosynthesize during the day making food and producing oxygen, and respire at night breaking down food, using up oxygen and producing carbon dioxide.) Explain the purpose of the nutrient enrichment jars and the procedures used in each one.

2a. Outline the five steps of the scientific method. Discussion: What is a reasonable hypothesis for this experiment? (The original hypothesis proposes that the algae in the nutrient enriched containers will grow more than those in the control jar.) How can this be determined? (Weigh the algae.)

2b. Weigh the algae in each jar. Follow these steps precisely for each container and record the results immediately after each measurement.

Place the algae from one container in a salad spinner.
Spin off the excess water for 20 spins.
Remove the algae from the salad spinner and place on the balance pan.
Pour the excess water in the salad spinner back into the jar.
Weigh the algae in grams.
Replace the algae.
Dry the balance pan before weighing algae from another container.

Discussion: What does the weight tell us about the algae? (if they are growing) Is there a difference in weights between treatments.

3. Draw conclusions: Plot the new data and explain any apparent trends. Discussion: Are the weights of the algae increasing or decreasing? Are the algae in the fertilized jars growing faster than algae in the control jar? What can we surmise from the results? What implications does this experiment have for the natural environment?

Note: The data may agree with the original hypothesis, that nutrient enrichment leads to more rapid algal growth rates. The data may also fail to support the initial hypothesis. In that case, encourage the participants to propose reasons for this. Ask if the data show that nutrient enrichment does not lead to increased algal growth. How would they modify the experiment to further investigate how algae respond to nutrient loading?

Closure:

Encourage discussion of the problems and solutions concerning excessive algal growth. Discussion: Are algae naturally occuring organisms? Can they be a problem? When? Where do excess nutrients come from in nature? How could increased algal production affect the resources of the water bodies in our watershed? Why should we be concerned about the effects of increased nutrients in the water? How can planners and regulators use these findings? How can research such as this help land use planners?

Extensions:

1. The Water Quality Sampling Activity further investigates nutrient loading.

2. Participants can collect algae themselves and set up their own experiiment.

3. Invite someone with knowledge of the issues to come and speak on the nutrient loading.

4. Translate the graph into pie charts, bar graphs, 3-D graphs using computers.

Activity: Plotting Dissolved Oxygen

Ages 12 - 100

Goal:
To observe how graphing dissolved oxygen data may reveal a pattern that helps to explain the data.

Summary:
1. Participants discuss the relationship of eutrophication to dissolved oxygen content.

2. D.O. concentrations over time are graphed and patterns are interpreted.

Time, Place and Materials
This activity takes about 20 minutes in a place conducive to writing. Materials include:

* D.O. data from Waquoit Bay
*graph paper
*pencils

Background Information: Primer for Educators, "Eutrophication," p. II-5.

Introduction and Motivation:
If you did not do the Water Quality Testing activity, the "Fish Kill Mystery" from that activity can be used here. Discussion: What is the relationship between eutrophication and dissolved oxygen content? (Nutrient loading leads to increased algal growth and higher oxygen production and respiration. Cloudy days prevent photosynthesis and oxygen production, but respiration continues and D.O. levels can become dangerously low.)

Activity Procedure:
1. Hand out the data sheet of morning and evening dissolved oxygen contents in Waquoit Bay. Ask participants to comment on the pattern they observe. Discussion: Why is the D.O. content higher at dusk than at dawn? (The plants have been photosynthesizing during the day.) What is happening to the D.O. at night? (The levels decrease as plants and animals respire.)

2. Small groups graph the information on the chart with appropriate scales and labels for each axis.

3. Discussion: What effects might bad weather have on eutrophic ponds, lakes and bays? (Decreasing photosynthesis reduces O_2 production. Because respiration continues, anoxia could result.) What level of D.O. harms living organisms? (Below 4 ppm, waters are called hypoxic - low in oxygen - and some animals begin to die.) At what D.O. level is it impossible for anything to live? (0 parts ppm - called an anoxic event.) On what day, according to our graph, would a fish kill most likely have occurred? What other factors, beside cloudy weather, may have contributed to the fish kill ? (Windless conditions result in very little mixing or surface movement of the water. Seasonal growth of algae peak resulting in high levels of respiration at night and on cloudy days.)

Closure:
Invite the participants to compare graphs and explain the patterns the graphs illustrate and what the patterns mean. Ask each small group to write a statement, defining their conclusions.

Data Sheet for Plotting Dissolved Oxygen

Day	Time of Day	D.O. (ppm)	Sky Cover
1	Dawn	4	Sunny
1	Dusk	13	Sunny
2	Dawn	3	Sunny
2	Dusk	15	Sunny
3	Dawn	3	Cloudy
3	Dusk	8	Cloudy
4	Dawn	2	Cloudy
4	Dusk	4	Cloudy
5	Dawn	0.5	Cloudy
5	Dusk	1	Cloudy
6	Dawn	0	Cloudy
6	Dusk	5	Cloudy
7	Dawn	2.5	Sunny
7	Dusk	10	Sunny

Algal Growth Experiment Set-Up

Materials

1. Two gallon size (or larger) clear glass jars, or two small aquarium tanks.

2. Fish tank aerator with two air tubes and air stones on the ends, one for each jar.

3. Peter's Plant Food.

4. Salad spinner.

5. Balance, accurate to at least 2 grams.

6. Algae with water collected from the same water body. (This experiment can be done with freshwater or saltwater algae. Try to collect algae from a site where its growth has been a problem or a nuisance.)

Procedure

1 Fill the containers with water from the source where you collected the algae.

2. Label one jar the control jar and one jar the nutrient enriched jar.

3 Add 2 tablespoons of Peter's Plant Food per/gallon of water to the nutrient enriched jar.

4. Spin the algae in the salad spinner. Weigh the algae. Place10 grams of algae per gallon of water in each container

5. Plug in the fish tank aerator, with the air tubes and air stones attached. Leave the aerator on at all times.

6. Place the containers in a sunny window or protected outdoor area. Leave the top uncovered, or place cloth or screening over it.

7. Make a large chart to record weights and dates of fertilized and control groups. (The chart may be hung on a wall for easy visability.)

8 Replenish the water (with water from your source) every 5 days. Remove the algae from the jar, spin off the excess water with the salad spinner and measure.

9. Replace the algae in the proper jar.

10. Repeat steps 1 - 9.

Activity: Critiquing the Press

Ages 10 - 100

Goal:

Participants exercise and gain confidence in their knowledge of nutrient loading and its association to fish kills.

Summary:

1. The class reads a newspaper article about watershed issues and propose changes in the arrangement of the information.

2. Small groups write their own articles to present the information in a more clear and correct format.

3. Small groups may critique each other's articles; they may support or disagree with any of the content.

Note: Obtain an article that is relevant to watershed issues in your area. Try to choose an article that covers issues on nutrient loading, and that contains some unclear, incorrect or even jumbled information that the participants can correct. This is a great morale booster, and really gives participants the feeling that they have the knowledge, and therefore the power, to change things.

Time, Place and Materials

This activity takes 15 to 30 minutes in an area conducive to writing. Materials include:
*copies of an article about nutrient loading, fish kills, etc.
Background Information: Primer for Educators, "Fish Kills," p. II - 7.

Introduction and Motivation:

Review the events leading up to a problem associated with nutrient loading in your watershed area Assign small groups of 2 - 4 to formulate their own statement of what causes the problem.

Activity Procedure:

1. Pass out the article. After everyone has finished reading, ask them to comment on the information. List any information that the group thinks is incorrect. Then list any information that they think is unclear. Finally list what they think is accurate and they would keep in the article.

2 The small groups should now rewrite the article, organizing the information clearly.

3. After the articles are written, small groups may share what they have written. Other participants may comment on the content of other articles. Allow time for peer interaction.

Extensions:

1. The Algal Growth Experiment Activity allows participants to see first hand the effects of algal blooms in a watery habitat.

2. The participants could publish their story and pass it out to interest groups or schools, or turn it into an informational pamphlet.

Part IV

Appendices

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Glossary

algae - primitive, chiefly unicellular organisms containing chlorophyll and lacking true stems, roots or leaves.

aquifer - underground sediments saturated with water.

brackish - refers to water bodies that have salinity levels in between that of seawater and freshwater.

Cladophora - a dominant species of algae in Waquoit Bay, characterized by slow and steady growth rates.

density - weight per unit volume

drainage area - the region from which all groundwater flows to a common place

estuary - a place where fresh and saltwater meet; typical habitats include salt marshes, sandy beaches, and rocky beaches

eutrophication - the addition of excessive quantities of nutrients to water bodies, usually resulting in the rapid growth of particularvarieties of vegetationand the decline of other animal and plant species

Gracilaria - a dominant species of algae in Waquoit Bay that is nitrogen limited

ground water - water stored in and moving through the aquifer

impermeable - does not allow water to pass through it

kettle holes - depressions created by blocks of ice left by glaciers in the outwash plain

kettle ponds - kettle holes that have since filled with water, either by being fed by a stream or because they lie below the water table

leachate - components draining from a source (e.g. a landfill) and moving with water through the soil

limiting factor - the variable, or combination of variables, which limits the rate of growth of an organism or a population, or which limits the rate of a physiological process.

moraine - a bed of sediments deposited by a glacier; usually unsorted, containing all sizes of sediment from mud grains to boulders.

nitrogen - an element necessary for life; often the limiting nutrient for plants in marine environments; a major component in fertilizersas well as human waste

nutrient limited - refers to a plan or animal that would grow more rapidly and perhaps reproduce more frequently if more nutrients were available. The available amounts of nitrogen and phosphorous often limit the growth of plants.

outwash plain - gravel and/or sand deposited by glacial meltwater; generally characterized by high permeability

percolation - flow of water through cracks and pores in sediments

permeability - the rate at which fluid moves through the pore spaces in a sediment

plume - detectable flow of contaminated ground water porosity - the total volume of pore space in a

sediment recharge - resuppply of water to an aquifer

surface runoff - precipitation or meltwater that flows over the land surface rather than percolating down into the sediments

water table - upper surface of an aquifer; boundary between the zone of saturation and the zone of aeration

watershed - a region from which all surface water flows to a common place

zone of aeration - the region where all poor spaces between sediment grains are filled with air

zone of contribution - the region of an aquifer that contributes water to a well

zone of saturation - the region where all pore spaces between sediment grains are filled with water